# PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

## PCT

### NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

| | |
|---|---|
| **Date of mailing** (day/month/year)<br>17 March 2000 (17.03.00) | |
| **International application No.**<br>PCT/EP99/04734 | **Applicant's or agent's file reference**<br>CE30513P/PCT |
| **International filing date** (day/month/year)<br>05 July 1999 (05.07.99) | **Priority date** (day/month/year)<br>11 July 1998 (11.07.98) |
| **Applicant**<br>O'NEILL, Rorie | |

1. The designated Office is hereby notified of its election made:

   [X] in the demand filed with the International Preliminary Examining Authority on:

   31 January 2000 (31.01.00)

   [ ] in a notice effecting later election filed with the International Bureau on:

   _____

2. The election [X] was

   [ ] was not

   made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

| | |
|---|---|
| **The International Bureau of WIPO**<br>**34, chemin des Colombettes**<br>**1211 Geneva 20, Switzerland** | Authorized officer<br>F. Baechler<br>Telephone No.: (41-22) 338 83 38 |

PATENT COOPERATION TREATY

# PCT

## INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

| Applicant's or agent's file reference | **FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below. | |
|---|---|---|
| CE30513P/PCT | | |
| International application No. | International filing date *(day/month/year)* | (Earliest) Priority Date *(day/month/year)* |
| PCT/EP 99/ 04734 | 05/07/1999 | 11/07/1998 |
| Applicant | | |
| MOTOROLA LIMITED et al. | | |

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 4 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 8

   [X] as suggested by the applicant.

   [ ] because the applicant failed to suggest a figure.

   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

NC

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REC'D 09 NOV 2000

# PATENT COOPERATION TREATY

# PCT

## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

| Applicant's or agent's file reference | FOR FURTHER ACTION | See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416) |
|---|---|---|
| CE30513P/PCT | | |
| International application No. | International filing date *(day/month/year)* | Priority date *(day/month/year)* |
| PCT/EP99/04734 | 05/07/1999 | 11/07/1998 |
| International Patent Classification (IPC) or national classification and IPC | | |
| H04Q7/00 | | |
| Applicant | | |
| MOTOROLA LIMITED et al. | | |

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 6 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 5 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

| Date of submission of the demand | Date of completion of this report |
|---|---|
| 31/01/2000 | 06.11.2000 |
| Name and mailing address of the international preliminary examining authority:<br>European Patent Office<br>D-80298 Munich<br>Tel. +49 89 2399 - 0 Tx: 523656 epmu d<br>Fax: +49 89 2399 - 4465 | Authorized officer<br>Kreppel, J<br>Telephone No. +49 89 2399 8246 |

Form PCT/IPEA/409 (cover sheet) (January 1994)

# INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/EP99/04734

## I. Basis of the report

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

**Description, pages:**

| | | | | |
|---|---|---|---|---|
| 1,4-14 | as originally filed | | | |
| 2,3 | as received on | 21/08/2000 | with letter of | 15/08/2000 |

**Claims, No.:**

| | | | | |
|---|---|---|---|---|
| 1-13 | as received on | 21/08/2000 | with letter of | 15/08/2000 |

**Drawings, sheets:**

| | |
|---|---|
| 1/5-5/5 | as originally filed |

2. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

## V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

| | | | |
|---|---|---|---|
| Novelty (N) | Yes: | Claims | 1-13 |
| | No: | Claims | |
| Inventive step (IS) | Yes: | Claims | 1-13 |
| | No: | Claims | |
| Industrial applicability (IA) | Yes: | Claims | 1-13 |
| | No: | Claims | |

2. Citations and explanations

**see separate sheet**

## With respect to item V:

### 1 Prior art

1.1 Reference is made to the following documents. The numbering will be adhered to in this report:

D1: WO 98 11698 A (JEDWAB JONATHAN ;DAVIS JAMES ANDREW (US); HEWLETT PACKARD CO (US)) 19 March 1998 (1998-03-19)

D2: WILKINSON T A ET AL: 'MINIMISATION OF THE PEAK TO MEAN ENVELOPE POWER RATIO OF MULTICARRIER TRANSMISSION SCHEMES BY BLOCK CODING' PROCEEDINGS OF THE VEHICULAR TECHNOLOGY CONFERENCE, CHICAGO, JULY 25 - 28, 1995, vol. 2, no. CONF. 45, 25 July 1995 (1995-07-25), pages 825-829, XP000551649 INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS ISBN: 0-7803-2743-8

D3: WO 97 26743 A (JONES ALAN EDWARD ;MOTOROLA LTD (GB); WILKINSON TIMOTHY ALAN (GB);) 24 July 1997 (1997-07-24)

1.2 The invention relates to a communication system with reduced power variation wherein data is transmitted over a plurality of subchannels according to the preamble of claim 1 and to a method of reducing power variation in a communication system according to the preamble of independent claim 13.

A communication system with reduced power variation is known from document D1 which is regarded to represent the closest prior art to the subject-matter of the present application. According to D1, a number of information symbols is mapped into a larger number of channel symbols using a generator matrix. These channel symbols are then transmitted using e.g. orthogonal frequency division modulation.

However, for a communication system according to D1, the number of channels and therefore the required bandwidth increases.

## 2 Object

It is therefore an object of the present invention to modify a communication system with reduced power variation so that the required bandwidth does not increase.

## 3 Solution

This is achieved by a communication system comprising the following combination of features:

- data is transmitted over a plurality of subchannels;

- at least one means of generating information symbols;

- at least one encoder for encoding information symbols into higher order channel symbols utilizing a forward error correction scheme and selecting between redundant symbol values to reduce power variation whereby one channel symbol is generated for each information symbol;

- a subchannel transmitter transmitting the channel symbols on individual subchannels in a combined signal.

The inventive concept is based on the idea to map each information symbol onto a higher order channel symbol separately. A binary information symbol can thus be mapped e.g. onto an octary channel symbol inserting redundancy without increasing the bandwidth or utilizing additional channels. The channel symbols can be selected from a plurality of redundant channel symbols such that the power variation of the combined signal is minimized.

## 4 Conclusions

The subject-matter of independent claims 1 and 13 therefore meets the requirements of Article 33 (2)-(4) PCT regarding novelty, inventive step and industrial applicability. Claims 2 to 12 are dependent on claim 1 and therefore also

novel, inventive and industrially applicable.

The subject-matter of independent claims 1 and 13 is also not anticipated or rendered obvious by the other documents cited in the international search report. Documents D2 and D3 disclose also methods for reducing power variation of a OFDM signal. According to these documents, block coding is applied increasing the number of channel symbols.

# PCT REQUEST

For receiving Office use only

PCT/EP 99 / 04734
International Application No.

05 JUL 1999 (05. 07. 1999)
International Filing Date

EUROPEAN PATENT OFFICE
PCT INTERNATIONAL APPLICATION
Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference
*(if desired)(12 characters maximum)* CE30513P/PCT

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

**Box No. I** **TITLE OF INVENTION: COMMUNICATION SYSTEM WITH REDUCED POWER VARIATION AND METHOD THEREFORE**

**Box No. II** **APPLICANT**

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

Motorola Limited
Viables Industrial Estate
Basingstoke, Hampshire
RG22 4PD, United Kingdom

☐ This person is also inventor.

Telephone No.

Facsimile No.

Teleprinter No.

State *(i.e. country)* of nationality: GB

State *(i.e. country)* of residence: GB

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

**Box No. III** **FURTHER APPLICANTS AND/OR (FURTHER) INVENTORS**

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

O'NEILL, Rorie
25 Applewood Court
Westlea
Swindon
Wiltshire, Swindon, SN2 7AH

This person is:

☐ applicant only
☒ applicant and inventor
☐ inventor only *(if this check-box is marked, do not fill in below.)*

State *(i.e. country)* of nationality: GB

State *(i.e. country)* of residence: GB

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☐ Further applicants and/or (further) inventors are indicated on a continuation sheet.

**Box No. IV** **AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE**

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name: for a legal entity, full official designation. The address must include postal code and name of country)*

IBBOTSON, Harry
Motorola, European Intellectual Property Operations
Midpoint, Alencon Link
Basingstoke, Hampshire
RG21 7PL, United Kingodm

Telephone No.
00 44 1256 790790

Facsimile No.
00 44 1256 811319

Teleprinter No.

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.



*See Notes to the request form*

PCT/EP 99 / 04734

**Box No.V DESIGNATION OF STATES**

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked)*:

**Regional Patent**

- ☐ AP **ARIPO Patent:** GH Ghana, GM Gambia, KE Kenya, LS Lesotho, MW Malawi, SD Sudan, SL Sierra Leone, SZ Swaziland, UG Uganda, ZW Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT
- ☐ EA **Eurasian Patent:** AM Armenia, AZ Azerbaijan, BY Belarus, KG Kyrgyzstan, KZ Kazakhstan, MD Republic of Moldova, RU Russian Federation, TJ Tajikistan, TM Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT
- ☒ EP **European Patent:** AT Austria, BE Belgium, CH and LI Switzerland and Liechtenstein, CY Cyprus, DE Germany, DK Denmark, ES Spain, FI Finland, FR France, GB United Kingdom, GR Greece, IE Ireland, IT Italy, LU Luxembourg, MC Monaco, NL Netherlands, PT Portugal, SE Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT
- ☐ OA **OAPI Patent:** BF Burkina Faso, BJ Benin, CF Central African Republic, CG Congo, CI Côte d'Ivoire, CM Cameroon, GA Gabon, GN Guinea, GW Guinea-Bissau, ML Mali, MR Mauritania, NE Niger, SN Senegal, TD Chad, TG Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* .....

**National Patent** *(if other kind of protection or treatment desired, specify on dotted line)*:

- ☐ AE United Arab Emirates
- ☐ AL Albania .....
- ☐ AM Armenia .....
- ☐ AT Austria .....
- ☐ AU Australia .....
- ☐ AZ Azerbaijan
- ☐ BA Bosnia and Herzegovina .....
- ☐ BB Barbados
- ☐ BG Bulgaria .....
- ☐ BR Brazil .....
- ☐ BY Belarus .....
- ☐ CA Canada
- ☐ CH and LI Switzerland and Liechtenstein
- ☐ CN China .....
- ☐ CU Cuba .....
- ☐ CZ Czech Republic .....
- ☐ DE Germany .....
- ☐ DK Denmark .....
- ☐ EE Estonia .....
- ☐ ES Spain .....
- ☐ FI Finland .....
- ☐ GB United Kingdom
- ☐ GD Grenada
- ☐ GE Georgia .....
- ☐ GH Ghana .....
- ☐ GM Gambia
- ☐ HR Croatia .....
- ☐ HU Hungary .....
- ☐ ID Indonesia
- ☐ IL Israel .....
- ☐ IN India .....
- ☐ IS Iceland
- ☒ JP Japan .....
- ☐ KE Kenya .....
- ☐ KG Kyrgyzstan .....
- ☐ KP Democratic People's Republic of Korea .....
- ☐ KR Republic of Korea .....
- ☐ KZ Kazakhstan .....
- ☐ LC Saint Lucia
- ☐ LK Sri Lanka
- ☐ LR Liberia
- ☐ LS Lesotho .....
- ☐ LT Lithuania
- ☐ LU Luxembourg
- ☐ LV Latvia
- ☐ MD Republic of Moldova .....
- ☐ MG Madagascar .....
- ☐ MK The former Yugoslav Republic of Macedonia .....
- ☐ MN Mongolia
- ☐ MW Malawi .....
- ☐ MX Mexico .....
- ☐ NO Norway
- ☐ NZ New Zealand .....
- ☐ PL Poland .....
- ☐ PT Portugal .....
- ☐ RO Romania
- ☐ RU Russian Federation .....
- ☐ SD Sudan
- ☐ SE Sweden
- ☐ SG Singapore
- ☐ SI Slovenia .....
- ☐ SK Slovakia .....
- ☐ SL Sierra Leone .....
- ☐ TJ Tajikistan .....
- ☐ TM Turkmenistan .....
- ☐ TR Turkey .....
- ☐ TT Trinidad and Tobago .....
- ☐ UA Ukraine .....
- ☐ UG Uganda .....
- ☒ US United States of America .....
- ☐ UZ Uzbekistan .....
- ☐ VN Viet Nam .....
- ☐ YU Yugoslavia .....
- ☐ ZA South Africa .....
- ☐ ZW Zimbabwe .....

Check-boxes reserved for designating States which have become party to the PCT after issuance of this sheet:

- ☐ .....
- ☐ .....

**Precautionary Designation Statement:** In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation of a designation consists of the filing of a notice specifying that designation and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.)*

**Supplemental Box** *If the Supplemental Box is not used, this sheet should not be included in the request.*

*1. If, in any of the Boxes, **the space is insufficient** to furnish all the information: in such case, write "Continuation of Box No. ..." [indicate the number of the Box] and furnish the information in the same manner as required according to the captions of the Box in which the space was insufficient, in particular:*

*(i) **if more than two persons are involved as applicants and/or inventors** and no "continuation sheet" is available: in such case, write "Continuation of Box No. III" and indicate for each additional person the same type of information as required in Box No. III. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below;*

*(ii) if, in Box No. II or in any of the sub-boxes of Box No. III, the indication **"the States indicated in the Supplemental Box"** is checked: in such case, write "Continuation of Box No. II" or "Continuation of Box No. III" or "Continuation of Boxes No. II and No. III" (as the case may be), indicate the name of the applicant(s) involved and, next to (each) such name, the State(s) (and/or, where applicable, ARIPO, Eurasian, European or OAPI patent) for the purposes of which the named person is applicant;*

*(iii) if, in Box No. II or in any of the sub-boxes of Box No. III, **the inventor or the inventor/applicant is not inventor for the purposes of all designated States or for the purposes of all designated States of America**: in such case, write "Continuation of Box No. II" or "Continuation of Box No. III" or Continuation of Boxes No. II and No. III" (as the case may be), indicate the name of the inventor(s) and, next to (each) such name, the State(s) (and/or, where applicable, ARIPO, Eurasian, European or OAPI patent) for the purposes of which the named person is inventor;*

*(iv) if, in addition to the agent(s) indicated in Box No. IV, there are **further agents**: in such case, write "Continuation of Box No. IV" and indicate for each further agent the same type of information as required in Box No. IV;*

*(v) if, in Box No. V, the name of any State (or OAPI) is accompanied by the indication **"patent of addition,"** or **"certificate of addition,"** or if, in Box No. V, the name of the United States of America is accompanied by an indication **"continuation"** or **"Continuation-in-part"**: in such case, write "Continuation of Box No. V" and the name of each State involved (or OAPI), and after the name of each such State (or OAPI), the number of the parent title or parent application and the date of grant of the parent title or filing of the parent application;*

*(vi) if, in Box No. VI, **there are more that three earlier applications whose priority is claimed**: in such case, write "Continuation of Box No. VI" and indicate for each additional earlier application the same type of information as required in Box No. VI.*

*(vii) if, in Box No. VI, **the earlier application is an ARIPO application**: in such case, write "Continuation of Box No VI", specify the number of the item corresponding to that earlier application and indicate at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed.*

*2. If, with regard to the **precautionary designation statement** contained in Box No. V. the applicant wishes to exclude any State(s) from the scope of that statement: in such case, write "Designation(s) excluded from precautionary designation statement" and indicate the name or two-letter code of each State so excluded*

*3. If the applicant claims, in respect of any designated Office, the benefits of provisions of the national law concerning **non-prejudicial disclosures or exceptions to lack of novelty:** in such case, write "Statement concerning non-prejudicial disclosures or exceptions to lack of novelty" and furnish that statement below*

Continuation of Box No. IV

IBBOTSON, Harry
GIBSON, Sarah
POTTS, Susan
HUDSON, Peter

All above attorneys/agents are members of Motorola, Inc., Intellectual Property Department and have the same address, telephone number and telegraphic address as indicated in Box IV.

 PCT/EP 99/04734

**Box No. VI PRIORITY CLA.** Further priority claims are indicated in the Supplemental Box ☐

Priority of the following earlier application(s) is claimed:

| Filing Date of earlier application (day/month/year) | Number of earlier application | Office where earlier application filed: National application = country; regional application = regional Office | International application = receiving Office |
|---|---|---|---|
| item (1) 11 JULY 1998 (11.07.98) | 9815025.3 | ~~United Kingdom~~ GB | |
| item (2) | | | |
| item (3) | | | |

☐ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office)* identified above as item(s): _____

* *Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii). See Supplemental Box.*

**Box No. VII INTERNATIONAL SEARCHING AUTHORITY**

**Choice of International Searching Authority (ISA)** *(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used):* ISA/ EP

**Request to use results of earlier search; reference to that search** *(if an earlier search has been carried out by or requested from the International Searching Authority):*

Date *(day/month/year)* Number: Country (or regional office):

**Box No. VIII CHECK LIST; LANGUAGE OF FILING**

This international application contains the following **number of sheets:**

| | | |
|---|---|---|
| 1. request | 5 | sheets |
| 2. description (excluding sequence listing part) | 14 | sheets |
| 3. claims | 5 | sheets |
| 4. abstract | 1 | sheets |
| 5. drawings | 5 | sheets |
| 6. sequence listing part of description | 0 | sheets |
| **Total** | 30 | sheets |

This international application is **accompanied** by the item(s) marked below:

1. ☒ fee calculation sheet
2. ☐ separate signed power of attorney
3. ☒ copy of general power of attorney
4. ☐ statement explaining lack of signature
5. ☐ priority document(s) identified in Box No. VI as item(s):
6. ☐ translation of international application into (language): _____
7. ☐ separate indications concerning deposited microorgs./biological mat.
8. ☐ nucleotide and/~~or~~ amino acid sequence listing in computer readable form
9. ☐ other *(specify)*: copy, U.S. assignment

**Figure No. 8 of the drawings** (if any) should accompany the abstract when it is published.

**Language of filing of the international application: EN**

**Box No. IX SIGNATURE OF ~~APPLICANT OR AGENT~~**

*Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).*

MOTOROLA LIMITED
BY
H. IBBOTSON
ATTORNEY

For receiving Office use only

1. Date of actual receipt of the purported international application:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application: 05 JUL 1999 (05.07.1999)
4. Date of timely receipt of the required corrections under PCT Article II(2):
5. International Searching Authority specified by the applicant: ISA/
6. ☐ Transmittal of search copy delayed until search fee is paid

2. Drawings:
☒ received:
☐ not received:

For International Bureau use only

Date of receipt of the record copy by the International Bureau:



*See Notes to the request form*

# COMMUNICATION SYSTEM WITH REDUCED POWER VARIATION AND METHOD THEREFOR

## Field of the Invention

The present invention relates to a communication system with reduced power variation wherein data from a transmitter is transmitted to a receiver over a plurality of subchannels and a method therefor. The invention is applicable but not limited to a cellular communication system.

## Background of the Invention

In a cellular communication system each of the mobile stations communicate with typically a fixed base station. Communication from the mobile station to the base station is known as uplink and communication from the base station to the mobile station is known as downlink. The total coverage area of the system is divided into a number of separate cells each covered by a single base station. The cells are typically geographically distinct with an overlapping coverage area with neighbouring cells. As a mobile station moves from the coverage area of one cell to the coverage area of another cell, the communication link will change from being between the mobile station and the base station of the first cell to being between the mobile station and the base station of the second cell. This is known as a handover. Specifically, some cells may lie completely within the coverage of other larger cells.

All base stations are interconnected by a fixed network. This fixed network comprises communication lines, switches, interfaces to other communication networks and various controllers required for operating the network. A call from a mobile station is routed through the fixed network to the destination specific for this call. If the call is between two mobile stations of the same communication system the call will be routed through the fixed network to the base station of the cell in which the other mobile station currently is. A connection is thus established between the two serving cells through the fixed network. Alternatively, if the call is between a mobile station and a telephone connected to the

New Page 15/8/00



Public Switched Telephone Network (PSTN) the call is routed from the serving base station to the interface between the cellular mobile communication system and the PSTN. It is then routed from the interface to the telephone by the PSTN.

Many different modulation methods are known for communication in cellular and other communication schemes. Some of these involve the transmission of data from a transmitter to a receiver over a plurality of distinct subchannels. Examples of this include Orthogonal Frequency Division Multiplex (OFDM) or multicode Code Division Multiple Access (CDMA) schemes. A common characteristic of these modulation schemes is that the transmitted power varies substantially dependent on the data in the subchannels resulting in a high peak to average ratio of the transmitted power.

A method of reducing this ratio is described in WO98/11698, which describes and OFDM system where 'n' bit data words are encoded as $2^m$ symbol words, with the symbol words being generated to result in a desired low peak to average ratio. The document discloses introduction of error correction by increasing the size of the code word relative to the data word and transmitting the additional symbols over additional subchannels.

In order to limit degradation and spectral spreading of the transmission, a high peak to average ratio of the transmit power requires that the output power amplifier has to be linear over a wide dynamic range. This significantly impairs the cost and efficiency of the power amplifier. This is especially a problem in mobile communication systems where a low efficiency of the output amplifier significantly reduces the battery life of the mobile station.

Substantial benefits can thus be obtained by reducing the variations of the transmit power.

## Summary of the Invention

The invention seeks to provide a system for reducing the peak to average of transmissions in a communication system using a subchannel modulation scheme.

According to a first aspect of the invention, there is provided a communication system with reduced power variation wherein data is transmitted over a plurality of subchannels comprising at least one means of generating information symbols, a subchannel

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transmitter for transmission of channel symbols on individual subchannels in a combined signal, at least one encoder for encoding information symbols into higher order channel symbols at substantially the same symbol rate, the encoding both being in response to a forward error correction scheme and including selection between redundant symbol values to reduce power variation of the combined signal, and a subchannel receiver receiving the higher order channel symbols and regenerating the information symbols, characterized in that one channel symbol is generated for each information symbol.

Preferably, the average symbol energy of the channel symbols is substantially the same as the information symbols and the encoding of information symbols into higher order channel symbols is done independently for each subchannel.

According to a preferred feature of the invention the forward error correcting scheme is a trellis coding scheme.

According to a second preferred feature of the invention, the encoder comprises a first data input for the information symbols and at least a second data input for compensation data, the communication system further comprising means for generating compensation data reducing the amplitude variations of the combined signal.

Preferably, the communication scheme employed is an Orthogonal Frequency Division Multiplex (OFDM) subchannel communication scheme or a multicode Code Division Multiple Access (CDMA) subchannel communication scheme.

According to a second aspect of the invention, there is provided a method of reducing power variation in a communication system wherein data is transmitted over a plurality of subchannels, the method comprising generating information symbols, transmitting channel symbols on individual subchannels in a combined signal, encoding information symbols into higher order channel symbols at substantially the same symbol rate, the encoding both being in response to a forward error correction scheme and including selection between redundant symbol values to reduce power variation of the combined signal, and receiving the higher order channel symbols and regenerating the information symbols.

The invention thus enables a reduction in the power variation of a subchannel transmitter without degrading performance or increasing transmission bandwidth by increasing the order of the channel symbols, introducing forward error correction coding and selecting between redundant symbol values so that power variation is minimised.

## Brief Description of the Drawings

An embodiment of the present invention is described below, by way of example only, with reference to the accompanying drawing, in which:

FIG. 1 is an illustration of a cellular communication system according to prior art.

FIG. 2 is a block diagram of an example of a single communication link between one mobile station and one base station using a subchannel modulation scheme using conventional means.

FIG. 3 is a block diagram of a conventional 4 subchannel transmitter using an OFDM modulation scheme .

FIG. 4 is a block diagram of a conventional OFDM subchannel receiver 400 for four subchannels.

FIG. 5 is a block diagram of conventional 2 channel subchannel transmitter using a multicode CDMA subchannel modulation scheme.

FIG. 6 is a block diagram of a conventional multicode CDMA 2 channel subchannel receiver.

FIG. 7 is an illustration of the possible constellation points for a QPSK symbol and of a short section of the spreading codes for the two subchannels.

FIG. 8 is a block diagram of a 4 channel OFDM subchannel transmitter in accordance to the invention.

FIG. 9 is an illustration of the constellation points for a BPSK symbol and an 8-PSK symbol.

FIG. 10 is an illustration of an example of a trellis coder.

## Description of a Preferred Embodiment

FIG. 1 illustrates a cellular communication system 100. In the system, a base station 101 communicates with a number of mobile station 103 over radio channels 105. In the cellular system, the base station 101 covers users within a certain geographical area 107 whereas other geographical areas 109, 111 are covered by other base stations 113, 115. Typically, each of the base stations 101, 113, 115 contain a broadcast carrier plus one or more traffic carriers.

FIG. 2 illustrates an example of a link between one mobile station 103 and one base station 101 using a subchannel modulation scheme. In the example, the data from a single data source 201 is separated into subchannels in a serial to parallel converter 203. Alternatively, the data on different subchannels may originate from different data sources. The serial to parallel converter 203 is connected to a subchannel transmitter 205 which modulates the data , amplifies and transmits the modulated signal over the radio channel 209 by use of an antenna 207. The signal is received by a receive antenna 211 connected to a subchannel receiver 213 which regenerates the data transmitted on each individual subchannel. In the example, the data received in the subchannels are combined into a single data stream by a parallel to serial converter 215.

FIG. 3 illustrates the principle of a 4 subchannel transmitter 300 using an OFDM modulation scheme. The data in each subchannel is fed to a symbol mapper 301-307 which maps the data into a complex symbol for transmission on the subchannel. The

complex symbols are fed to the OFDM modulator 309 which generates an OFDM modulated signal s(t) given by

$$s(t) = \sum_{i=-\infty}^{\infty}\sum_{k=0}^{3} \mathrm{Re}\left[d_{i,k} \cdot e^{j2\pi f_k t}\right] rect\left(\frac{t - iT - T/2}{T}\right)$$

where $d_{i,k}$ is data symbol i on subchannel k, $f_k$ the modulation frequency of subchannel k given by $f_k = k \cdot f_0$ where $f_0$ is the frequency of the subchannel with the lowest frequency. Re(x) denotes the real part of x and rect(x) is given by

$$\mathrm{Re}ct(x) = \begin{cases} 1 & 0 \le x < 1 \\ 0 & Otherwise \end{cases}$$

The individual subchannels carrying the subchannel information is thus combined into a combined signal by the OFDM modulator. The combined signal is frequency shifted to the carrier frequency in a multiplier (or mixer) 311 and fed to the antenna 207 through an amplifier 313.

FIG. 4 illustrates the principle of an OFDM subchannel receiver 400 for four subchannels. The signal from the receive antenna 211 is fed to a low noise amplifier 401 and the amplified signal is fed to a multiplier (or mixer) 403 down converting the signal to complex base band. The down-converted signal is fed to four complex multipliers and the output signal of each multiplier is fed to an integrator 413-419. The output signal on subchannel k is thus given by

$$r_k(f) = \int_{iT}^{(i+1)T} r(t) \cdot e^{-2\pi f_k t}\, dt$$

where r(t) is the down-converted received base band signal. In each subchannel the integration over a symbol period will result in the signals from other subchannels cancelling out whereas the signal in the current subchannel is restored to an integration of the basic pulse shape, in this case given by the rect(x) function. The output of the

integrators are fed to data detectors 421 - 427 which estimates the received symbol and maps it into the received data in the subchannel.

A more detailed description of OFDM modulation can be found in 'COFDM modulation: an overview' by W.Y.Zou and Y.Wu in IEEE Transactions on Broadcasting Vol. 41 No.1 pp 1-8, March 1995.

FIG. 5 illustrates an example of a 2 channel subchannel transmitter 500 using a multicode CDMA subchannel modulation scheme. The input data in the two subchannels are mapped into complex symbols by the symbol mappers 501, 503. The complex symbols are multiplied by a first spreading code in multipliers 505, 507. The first spreading code is different for each subchannel and preferably the spreading codes are orthogonal between the channels. The two channels are added together in an adder 509 and the sum is in this example spread by multiplication in a second multiplier 511 by a common spreading code. The output of the multiplier is fed to a quadrature modulator 513 and the resultant signal is amplified in an amplifier 515 before being transmitted by the antenna 517.

FIG. 6 illustrates the principle of a multicode CDMA 2 channel subchannel receiver 600. The radio signal is received by an antenna 601 and amplified in a low noise amplifier 603. The output of the amplifier 603 is fed to a quadrature down converter which generates complex base band signal. This signal is de-spread by the common spreading code in a multiplier 607 before being fed to multipliers 609, 611 where the signal is de-spread with the spreading code in each subchannel. The output of the multipliers 609, 611 is fed to symbol time integrators 613,614. The signal for the other subchannel will for orthogonal spreading codes integrate to zero whereas the wanted signal following de-spreading will be restored to the non spread signal transmitted in this subchannel. the output of the integrators is fed to data detectors 617,619 which estimates the received symbol and generates the received data in the subchannel.

Further description of CDMA communication systems can be found in ' Spread Spectrum CDMA Systems for Wireless Communications' by Savo Glisic and Branca Vucetic, Artech House, 1997, ISBN 0-89006-858-5 and in 'Multi-Carrier Spread Spectrum

Modulation with Reduced Dynamic Range' by V.Aue and G.P.Fettweis, proceedings of IEEE 46th Vehicular Technology Conference, 1996, p914.

In both OFDM and CDMA subchannel transmitters, the complex symbols transmitted will add up to a signal with varying amplitude as a consequence of the relative phase difference between the symbols. An example is given in FIG. 7 for a two channel CDMA transmitter using Quaternary Phase Shift Keying (QPSK).

FIG. 7(a) illustrates the possible constellation points A, B, C, D for a QPSK symbol and FIG. 7(b) illustrates an example of a short section of the spreading codes $S_1$ and $S_2$ for the two subchannels. Assuming the symbol constellation A is transmitted in both subchannels, the signals will add constructively during time interval $T_1$ and $T_3$ resulting in a summed signal corresponding to point E on FIG. 7(a). During time interval $T_2$ the two signals will have opposite phases due to the opposite signs of the spreading codes in this interval and the two signals will cancel out resulting in the constellation point F on FIG. 7(a). The amplitude variation of the transmitted signal is thus from $2\sqrt{2}$ during time interval $T_1$ and $T_3$ to zero during $T_2$.

If however symbol A is transmitted in the first subchannel and symbol B is transmitted in the second subchannel, the two channels will add together in point G during $T_1$ and $T_3$, and in point H during interval $T_2$. The amplitude of both point G and H is 2 and there is thus no amplitude variation in this case.

A high amplitude or power variation is disadvantageous in a transmitter as it requires a large dynamic range of linearity of the power amplifier. This significantly increases the complexity and cost of the amplifier and reduces the efficiency. Any non-linearity will furthermore distort the transmitted signal and increase the out of band transmission. The problems are enhanced in mobile stations where long battery life and low complexity amplifiers are required.

According to an embodiment of the present invention, the peak to average ratio of the transmit power level is reduced by mapping the information symbols into higher order

channel symbols and selecting between redundant symbol values so that the power variation is reduced. In addition, the order of the symbols are increased to allow forward error correcting coding to compensate for reduction in the minimum distance between the symbols.

The term 'information symbols' denotes the data symbols directly corresponding to the source data in the appropriate subchannel before any processing such as forward error correcting coding. 'Channel symbols' denote the symbols actually transmitted over the radio link and thus include any forward error correcting coding etc. A channel symbol being of higher order than an information symbol means that there are more constellation points of the symbol, such as for example a QPSK symbol being of higher order than a BPSK symbol.

The embodiment is described in more detail in the following for the specific example where the data to be transmitted on each subchannel is mapped into Binary Phase Shift Keying (BPSK) symbols. FIG. 8 illustrates the embodiment for a 4 channel OFDM subchannel transmitter 800 corresponding to the one illustrated in FIG. 3. The symbol mappers 301-307 are in this case specifically BPSK symbol mappers 801-807. The output of the symbol mappers 801-807 are fed to encoders 809-815 which encode the information symbols into channel symbols by increasing the order of the symbols and using the increased redundancy to reduce power variation and include forward error correcting coding.

Preferably, the encoder will map the BPSK signal into 8 point Phase Shift Keying (8 PSK) using 2 bit trellis coding. FIG. 9 illustrates the constellation points for a BPSK symbol (FIG. 9(a)) and an 8-PSK symbol (FIG. 9(b)). FIG. 10 illustrates an example of a trellis coder 1000 which comprises two data inputs 1001,1003, the second input being fed to a binary multiplier 1005 which together with two delay elements 1007, 1009 generates a third binary value and introduces convolutional encoding. The three binary data values are fed to a data mapper 1011 which maps the data vector into the corresponding constellation point. A more detailed description of trellis coding can be found in 'Trellis-coded Modulation with Redundant Signal Sets Part 1: Introduction' by G. Ungerboeck in

IEEE Communications Magazine, February 87 Vol 25 No 2 or in ' Trellis Coding' by Christian Schlegel, IEEE Press 1997, ISBN 0-7803-1052-7.

The BPSK data from the symbol mappers 801-807 are fed to the second data-input 1003 of the encoders 809-815. As can be seen from the mapping the data on the first data input 1001 shifts the channel symbol of the subchannel by 180°. By setting the first data input 1001 of each encoder the channel symbols on each subchannel can thus be rotated with respect to each other to reduce the power variation. The first data input 1001 is for each symbol and each encoder thus set to the value which for the current set of symbols across the sub-channels results in the lowest power variation with respect to the average power of the transmission.

The determination of the appropriate compensation data to be applied to the first input 1001 of each encoder is preferably achieved by evaluating the power variation for all possible settings and choosing the one with the lowest variation.

According to one embodiment all possible settings of the data compensation vector are evaluated for all possible combinations of the information symbols on the subchannels. This evaluation can be carried out prior to operation and the preferred compensation data can be stored in a memory unit. The memory input will for every symbol be fed the information symbols of all subchannels and will generate the corresponding compensation data which is fed to the first data input 1001 of all encoders.

Due to inter symbol interference the power level variation may not only depend on the channel symbols currently being transmitted but also on previously transmitted symbols. According to an alternative embodiment, the compensation data for the current symbol is determined in response not only to the current symbol but also to other symbols transmitted before or after the current symbol. Specifically, if transmission is of a bursty nature, the data transmitted in the entire burst is preferably considered when determining the compensation data for the information symbols of the burst. Preferably, this is achieved by evaluating the power level variation over the burst for all possible data combinations in the burst and for all possible compensation data combinations prior to

operation and the optimum choice of compensation data is stored in a memory unit. During operation the set of data to be transmitted during the burst is fed to the memory unit, and the corresponding set of compensation data is obtained on the output of the memory unit.

When receiving the transmitted signal, the receiver demodulates and decodes the trellis code as is known in the art. However, as the first data input 1001 does not carry any information but is solely used for reducing the power variation of the transmission, the corresponding bit can be ignored in the receiver.

As one channel symbol is generated for each information symbol, the symbol rate and thus bandwidth of the transmission does not increase by the trellis coding and power variation reduction. Furthermore, the energy per symbol of the information and channel symbols is preferably maintained identical. As the minimum distance between constellation points is reduced, the uncoded symbol error is increased but this is compensated for by the trellis coding. The invention thus provides reduction of the peak to average power ratio without increasing the transmit power or bandwidth of the transmission.

According to an alternative embodiment the forward error correcting coding is not done independently on each subchannel but is done by applying error correction to the set of data across the subchannels. In this embodiment the channel symbol in one subchannel will depend on the information symbols in other subchannels and not just on the information symbols in the current subchannel.

In a different embodiment of the invention applicable to a subchannel CDMA transmitter with QPSK information symbols, the information symbols are encoded into 16 QAM (Quadrature Amplitude Modulation) using Trellis Coding. This results in similar performance as QPSK for the same transmission bandwidth and power, and provides a redundant bit for rotating each channel symbol permitting reduction in power level variations. This embodiment is suitable for the Universal Mobile Telecommunication

System (UMTS) under standardisation by the European Telecommunication Standards Institute (ETSI).

It will be apparent to the person skilled in the art that other error correcting schemes such as block coding or convolutional coding can be used instead of Trellis Coding.

In addition to the forward error correcting coding introduced in the encoders, conventional forward error correcting coding can be applied to the data as is well known in the art. As a specific example referring to FIG. 2, a Viterbi coder can be inserted between data source 201 and the serial to parallel converter 203 or can be connected to each subchannel output of the serial to parallel converter 203. At the receive side, a Viterbi decoder will be inserted at the output of the parallel to serial converter 215 or at each subchannel input to the parallel to serial converter 215 respectively.

According to a different embodiment the compensation data is not simply ignored at the receiver but is demodulated and an estimate of the received redundant compensation data is derived. This estimate is used for evaluating a transmission quality preferably by evaluating the error probability of the received compensation data. For example, a memory unit containing the pre-calculated compensation data for the current information symbols as used in the transmitter can be included in the receiver. After demodulation and decoding the received information symbols can be used as input for the memory unit in the receiver which will output the corresponding compensation data. This can be compared to the received compensation data and the difference between the two will indicate the error probability and thus the transmission quality.

Each subchannel will typically have a specified transmission format associated with it and this may be predefined or adaptively modified according to the requirements and conditions of the communication system. According to one embodiment of the invention the transmission format is different on different subchannels. For example, one subchannel may use 8PSK channel symbols for transmission of BPSK information symbols whereas another subchannel may simultaneously employ 16 QAM channel symbols for transmission of QPSK information symbols. Another example is where

transmissions only occur on some subchannels whereas other subchannels have no transmissions. Preferably, the encoding is performed independently on each subchannel in this embodiment.

Alternatively or in addition the power level of the transmissions in each subchannel may be different and the corresponding encoding can vary accordingly. For example if four subchannels are transmitted at say twice the power level of four other subchannels, the encoding for reduced power variation according to the current invention may be applied to these four subchannels only.

The encoding and application of the described technique can be dynamically altered to suit the current needs and conditions. Specifically, in a cellular communication system the transmitted power of a mobile station will vary with the distance between the base station and the mobile station. When the mobile station is far from the base station the transmitted power will be close to the maximum and in order to ensure a high efficiency without distortion of the transmitted signal the power variations must be reduced to a minimum. However, when the mobile station is close to the base station a substantially lower power level is transmitted and the efficiency will not be significantly affected by power variations. At the low power level the power amplifier will furthermore not be close to clipping or non-linear amplification and the distortion is thus reduced significantly.

Accordingly, the technique for reducing power variations may only be applied to mobile stations close to the edges of the cells but not to mobile stations close to the base station and hence transmitting at low power. A more flexible approach is to alter the information and channel symbol transmission rates and thus the encoding algorithm according to the current conditions.

The symbol mappers, encoders and the memory unit are preferably implemented in a suitable processor, such as a microprocessor or digital signal processor with associated memory, or is alternatively implemented in an integrated circuit.

It will be apparent to the person skilled in the art that the function performed by the symbol mappers, encoders and memory unit can be integrated in a single unit which generates the channel symbols in response to the data. The single unit may furthermore include the serial to parallel converter.

The invention is applicable to cellular systems where the invention can be applied to only uplink transmissions, only downlink transmissions or to both uplink and downlink transmissions. It can furthermore be applied throughout the system or can be selectively employed for specific mobile stations or base stations.

It will be apparent to the person skilled in the art that the invention is not limited to a cellular communication system or to radio communication but is applicable to other subchannel transmission schemes.

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## Claims

1. A communication system with reduced power variation wherein data is transmitted over a plurality of subchannels including

at least one means of generating information symbols,

at least one encoder for encoding information symbols into higher order channel symbols at substantially the same symbol rate, the encoding both being in response to a forward error correction scheme and including selection between redundant symbol values to reduce power variation of the combined signal, and

a subchannel transmitter for transmission of channel symbols on individual subchannels in a combined signal, characterized in that one channel symbol is generated for each information symbol.

2. A communication system with reduced power variation as claimed in claim 1 wherein the encoding of information symbols into higher order channel symbols is done independently for each subchannel.

3. A communication system with reduced power variation as claimed in claim 1 wherein the forward error correcting scheme operates on a plurality of the subchannels.

4. A communication system with reduced power variation as claimed in claim 1 wherein the forward error correcting scheme is a trellis coding scheme.

5. A communication system with reduced power variation as claimed in claim 1 wherein BPSK information symbols are encoded into 8PSK channel symbols.

6. A communication system with reduced power variation as claimed in claim 1 wherein the encoder comprises a first data input for the information symbols and at least a second data input for compensation data, the communication system further comprising means for generating compensation data reducing the amplitude variations of the combined signal.

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7. A communication system with reduced power variation as claimed in claim 6 wherein the means for generating compensation data comprises a memory unit with pre-calculated compensation data.

8. A communication system with reduced power variation as claimed in claim 6 wherein the determination of the compensation data for the current information symbols is in response to the intersymbol interference to or from surrounding symbols.

9. A communication system with reduced power variation as claimed in claim 6 wherein the receiver generates estimates of the compensation data and evaluates a transmission quality in response to the estimates of the compensation data.

10. A communication system with reduced power variation as claimed in claim 1 wherein each subchannel has an associated transmission format and at least one characteristic of the transmission format of the subchannels is different between at least two subchannels.

11. A communication system with reduced power variation as claimed in claim 1wherein an Orthogonal Frequency Division Multiplex (OFDM) subchannel communication scheme is employed.

12. A communication system with reduced power variation as claimed in claim 1 wherein a multicode Code Division Multiple Access (CDMA) subchannel communication scheme is employed.

13. A method of reducing power variation in a communication system wherein data is transmitted over a plurality of subchannels, the method comprising

generating information symbols,

transmitting channel symbols on individual subchannels in a combined signal,

encoding information symbols into higher order channel symbols at substantially the same symbol rate, the encoding both being in response to a forward error correction scheme and including selection between redundant symbol values to reduce power variation of the combined signal, and

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receiving the higher order channel symbols and regenerating the information symbols, characterized in that one channel symbol is generated for each information symbol.

# COMMUNICATION SYSTEM WITH REDUCED POWER VARIATION AND METHOD THEREFOR

## Abstract of the Disclosure

The invention relates to a communication system employing subchannel communication such as OFDM or multicode CDMA. A significant disadvantage of subchannel communication is the power variation of the transmitted signal. The invention provides a system and method with reduced power variation without compromising performance or increasing transmission bandwidth. According to the invention the information symbols to be transmitted on the individual subchannel are fed to encoders (809-815) which maps the information symbols into channel symbols by increasing the order of the symbols. The encoding is both in response to a forward error correction scheme and includes selection between redundant symbol values to reduce power variation of the combined signal. The channel symbols are fed to a modulator (309) and the modulated signal is transmitted. preferably the encoder comprises a trellis coder jointly encoding the information symbols and compensation data set to reduce the power level variation.

FIG. 8 to accompany the Abstract

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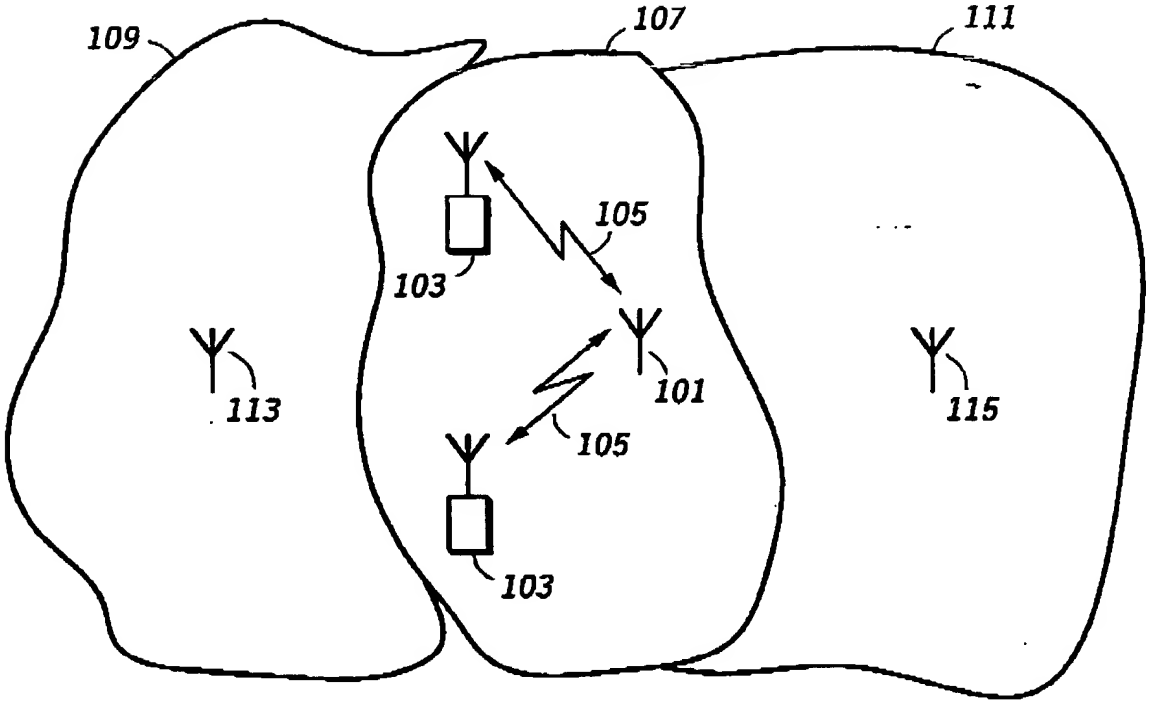


FIG.1
-PRIOR ART-

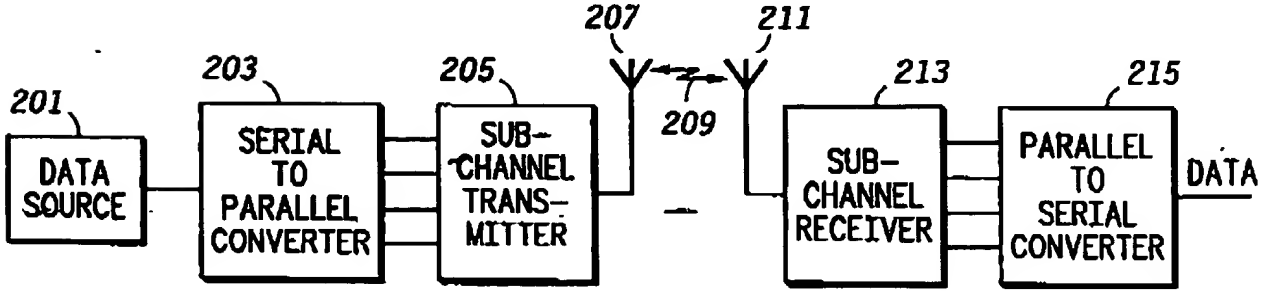


FIG.2

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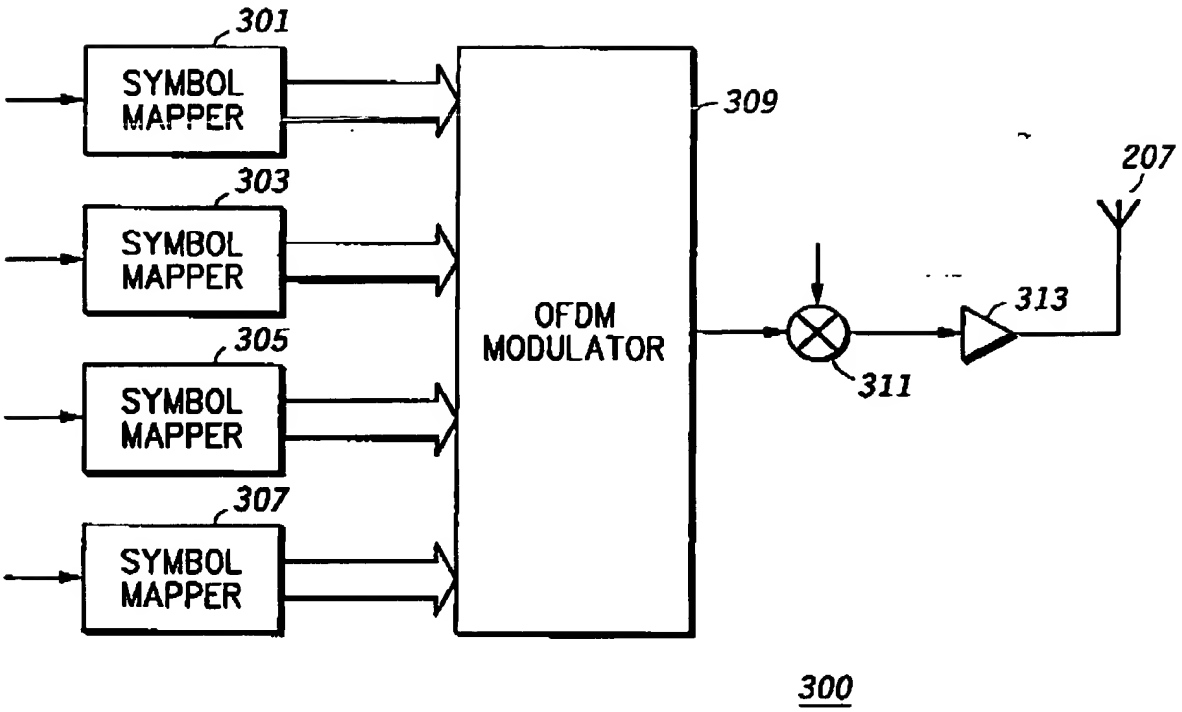



FIG. 3

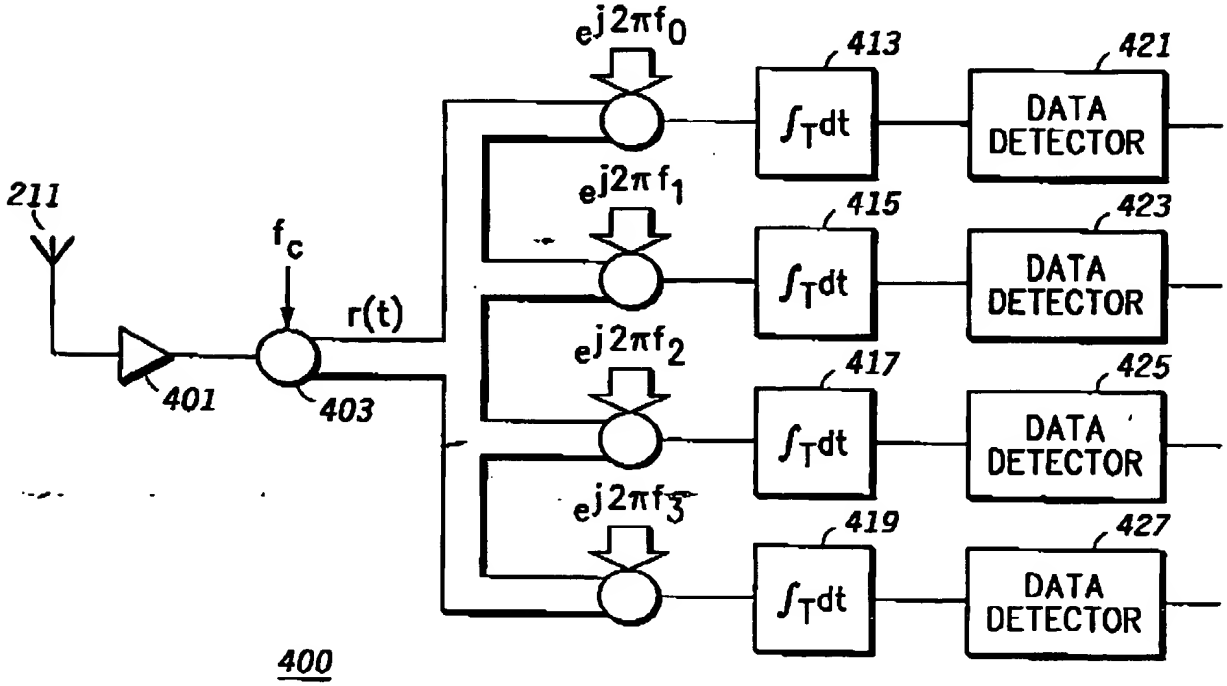
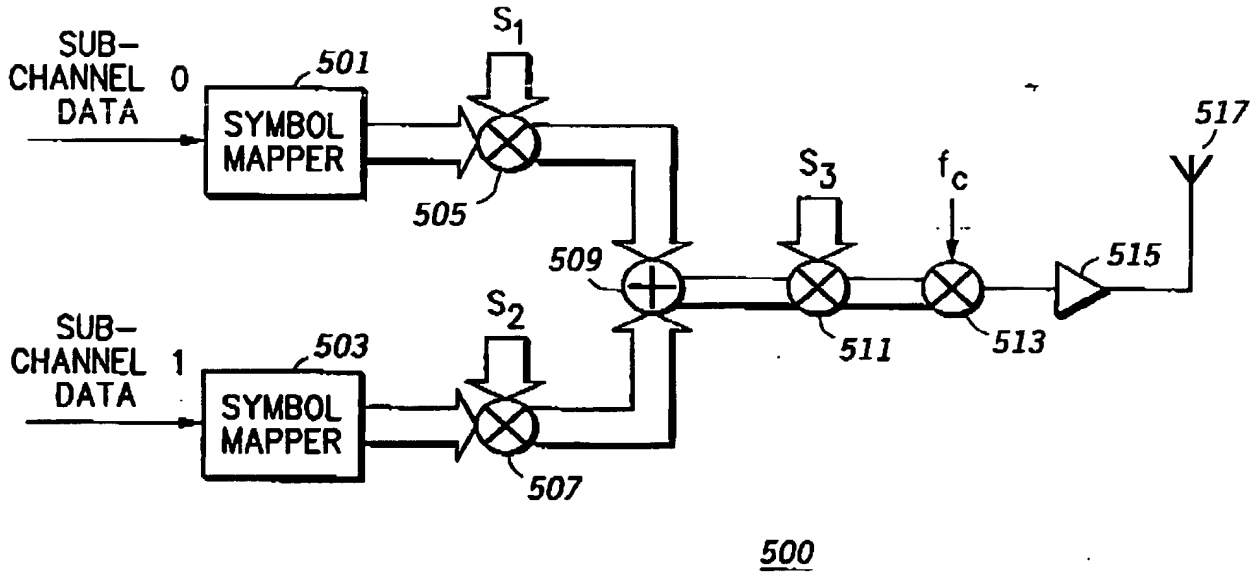



FIG. 4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SYMBOL MAPPER
501
$S_1$
505
SUB-CHANNEL DATA 1
SYMBOL MAPPER
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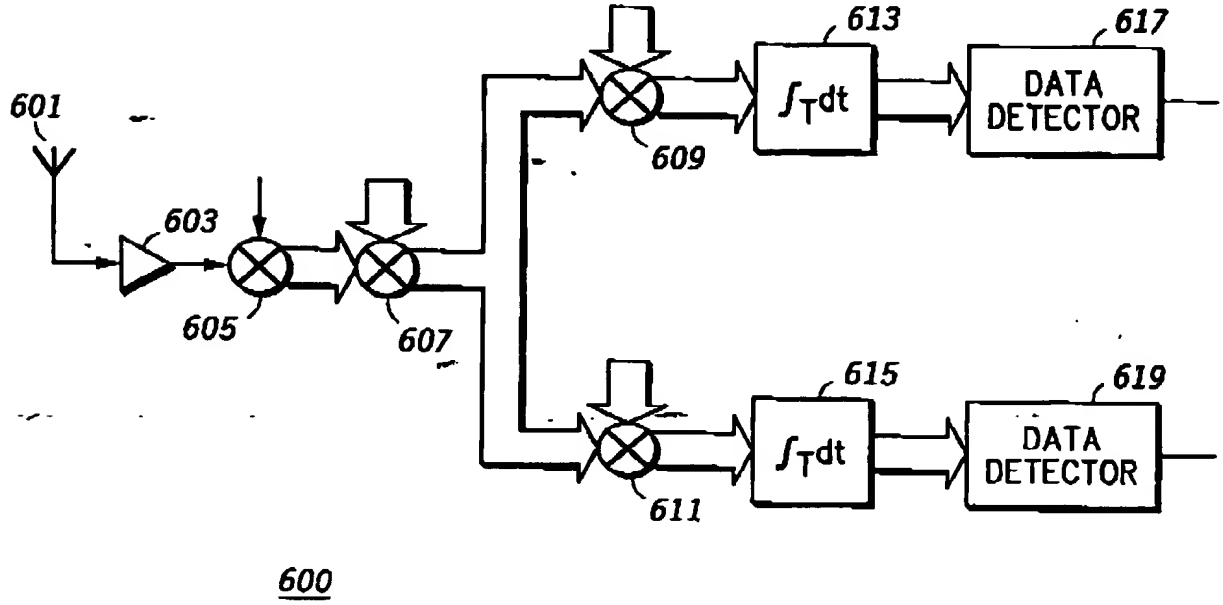
509
$S_3$
511
$f_c$
513
515
517
500

FIG. 5


601
603
605
607
609
613
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DATA DETECTOR
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611
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DATA DETECTOR
619
600

FIG. 6

09/743593



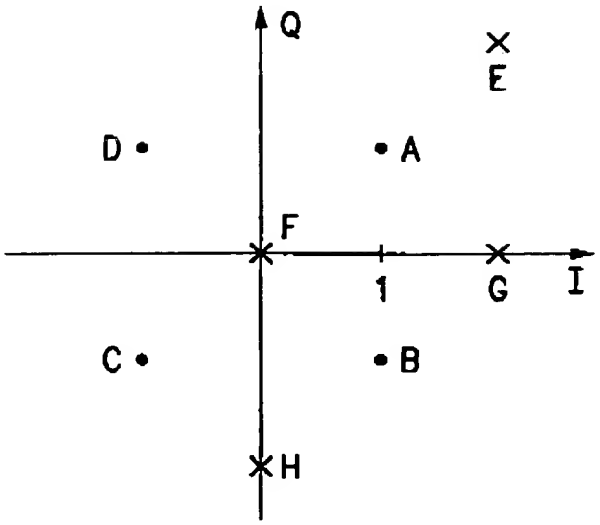



FIG. 7A

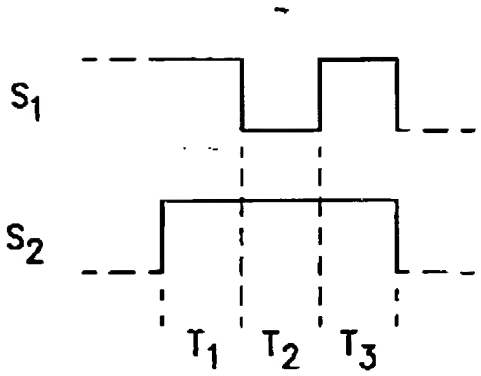



FIG. 7B

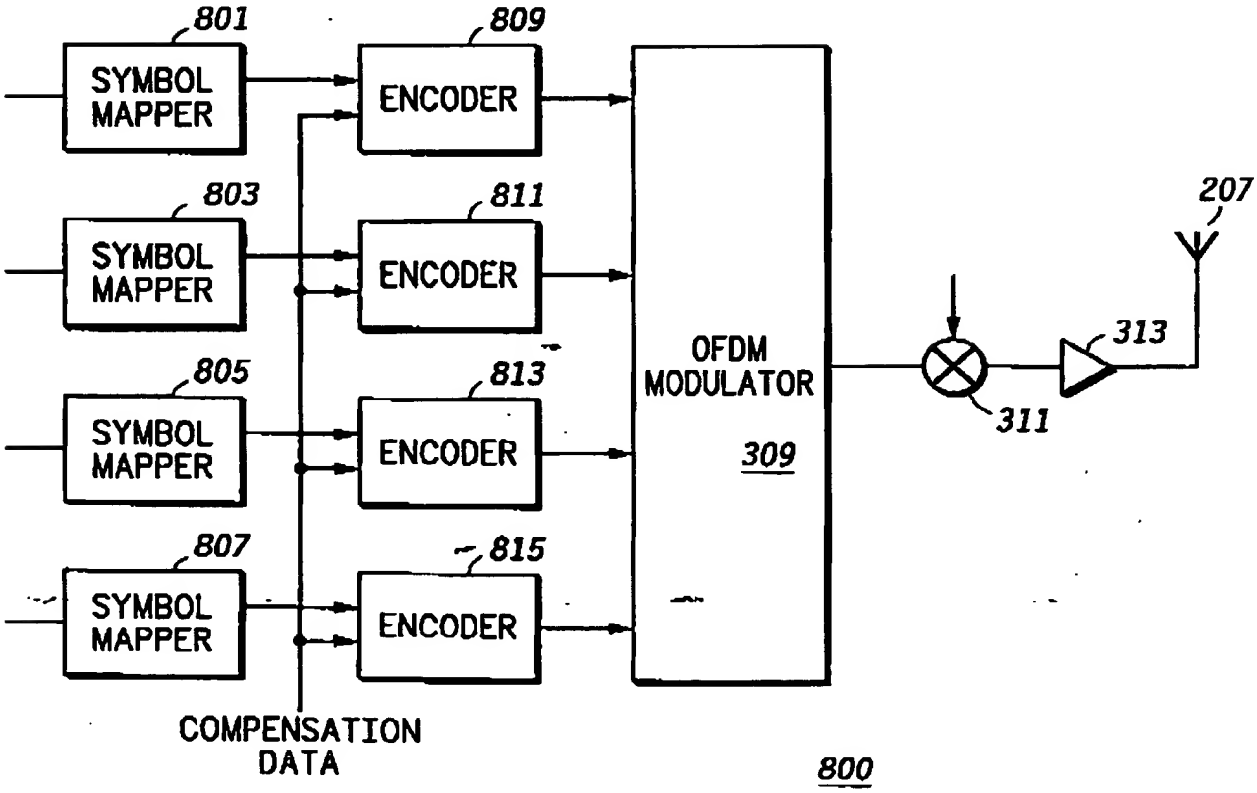



FIG. 8

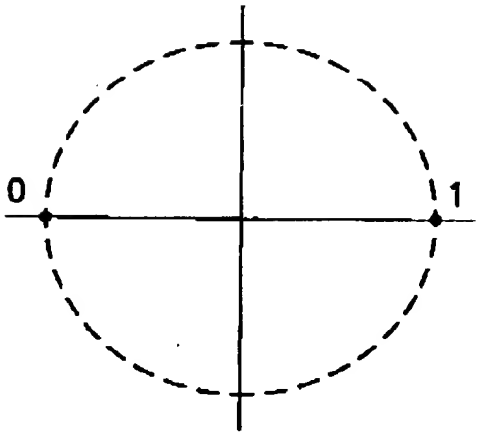



FIG.9A

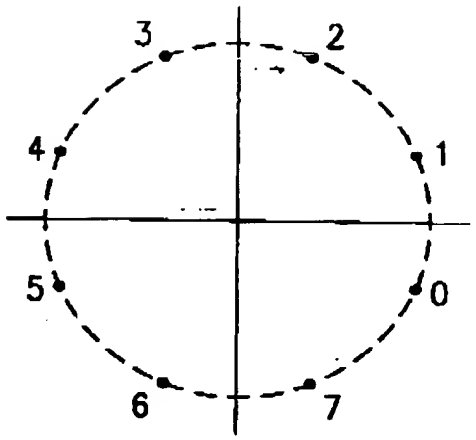
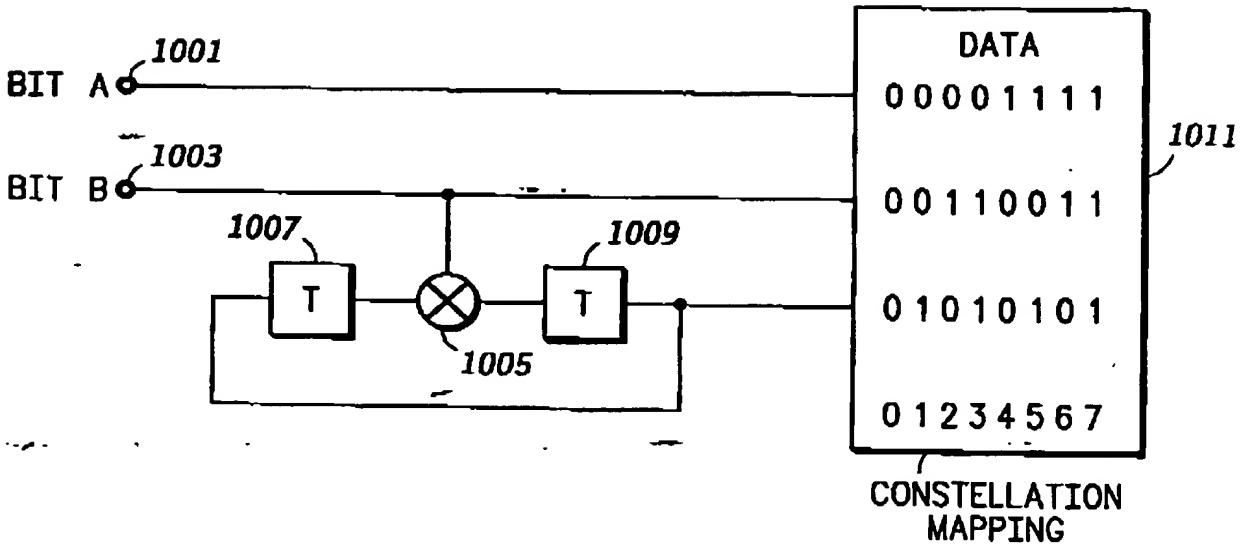



FIG.9B




1000

FIG.10

Public Switched Telephone Network (PSTN) the call is routed from the serving base station to the interface between the cellular mobile communication system and the PSTN. It is then routed from the interface to the telephone by the PSTN.

Many different modulation methods are known for communication in cellular and other communication schemes. Some of these involve the transmission of data from a transmitter to a receiver over a plurality of distinct subchannels. Examples of this include Orthogonal Frequency Division Multiplex (OFDM) or multicode Code Division Multiple Access (CDMA) schemes. A common characteristic of these modulation schemes is that the transmitted power varies substantially dependent on the data in the subchannels resulting in a high peak to average ratio of the transmitted power.

In order to limit degradation and spectral spreading of the transmission, a high peak to average ratio of the transmit power requires that the output power amplifier has to be linear over a wide dynamic range. This significantly impairs the cost and efficiency of the power amplifier. This is especially a problem in mobile communication systems where a low efficiency of the output amplifier significantly reduces the battery life of the mobile station.

Substantial benefits can thus be obtained by reducing the variations of the transmit power.

## Summary of the Invention

The invention seeks to provide a system for reducing the peak to average of transmissions in a communication system using a subchannel modulation scheme.

According to a first aspect of the invention, there is provided a communication system with reduced power variation wherein data is transmitted over a plurality of subchannels comprising at least one means of generating information symbols, a subchannel transmitter for transmission of channel symbols on individual subchannels in a combined signal, at least one encoder for encoding information symbols into higher order channel

symbols at substantially the same symbol rate, the encoding both being in response to a forward error correction scheme and including selection between redundant symbol values to reduce power variation of the combined signal, and a subchannel receiver receiving the higher order channel symbols and regenerating the information symbols.

Preferably, the average symbol energy of the channel symbols is substantially the same as the information symbols and the encoding of information symbols into higher order channel symbols is done independently for each subchannel.

According to a preferred feature of the invention the forward error correcting scheme is a trellis coding scheme.

According to a second preferred feature of the invention, the encoder comprises a first data input for the information symbols and at least a second data input for compensation data, the communication system further comprising means for generating compensation data reducing the amplitude variations of the combined signal.

Preferably, the communication scheme employed is an Orthogonal Frequency Division Multiplex (OFDM) subchannel communication scheme or a multicode Code Division Multiple Access (CDMA) subchannel communication scheme.

According to a second aspect of the invention, there is provided a method of reducing power variation in a communication system wherein data is transmitted over a plurality of subchannels, the method comprising generating information symbols, transmitting channel symbols on individual subchannels in a combined signal, encoding information symbols into higher order channel symbols at substantially the same symbol rate, the encoding both being in response to a forward error correction scheme and including selection between redundant symbol values to reduce power variation of the combined signal, and receiving the higher order channel symbols and regenerating the information symbols.

## Claims

1. A communication system with reduced power variation wherein data is transmitted over a plurality of subchannels including

at least one means of generating information symbols,

at least one encoder for encoding information symbols into higher order channel symbols at substantially the same symbol rate, the encoding both being in response to a forward error correction scheme and including selection between redundant symbol values to reduce power variation of the combined signal, and

a subchannel transmitter for transmission of channel symbols on individual subchannels in a combined signal.

2. A communication system with reduced power variation wherein data is transmitted over a plurality of subchannels further including

a subchannel receiver receiving the higher order channel symbols and regenerating the information symbols.

3. A communication system with reduced power variation as claimed in claim 1 or 2 wherein the encoding of information symbols into higher order channel symbols is done independently for each subchannel.

4. A communication system with reduced power variation as claimed in claim 1 or 2 wherein the forward error correcting scheme operates on a plurality of the subchannels.

5. A communication system with reduced power variation as claimed in any preceding claim wherein the forward error correcting scheme is a trellis coding scheme.

6. A communication system with reduced power variation as claimed in any of the preceding claims 1 to 5 wherein BPSK information symbols are encoded into 8PSK channel symbols.

7. A communication system with reduced power variation as claimed in any of the preceding claims 1 to 5 wherein QPSK information symbols are encoded into 16 QAM channel symbols.

8. A communication system with reduced power variation as claimed in any of the preceding claims wherein the encoder comprises a first data input for the information symbols and at least a second data input for compensation data, the communication system further comprising means for generating compensation data reducing the amplitude variations of the combined signal.

9. A communication system with reduced power variation as claimed in claim 8 wherein the encoder determines the channel symbols in response to the combination of the information symbols and compensation data.

10. A communication system with reduced power variation as claimed in claim 8 or 9 wherein the means for generating compensation data comprises a memory unit with pre-calculated compensation data.

11. A communication system with reduced power variation as claimed in claim 8, 9 or 10 wherein the determination of the compensation data for the current information symbols includes intersymbol interference to or from surrounding symbols.

12 A communication system with reduced power variation as claimed in any of the claims 8,9,10 or 11 wherein transmission occurs in bursts and the compensation data is determined in response to all information symbols transmitted during a burst.

13. A communication system with reduced power variation as claimed in claim 8 or 9 wherein the receiver generates estimates of the compensation data and evaluates a transmission quality in response to the estimates of the compensation data.

14. A communication system with reduced power variation as claimed in claim 13 wherein the transmission quality is determined by comparing the estimates of the

compensation data with a local replica of the compensation data corresponding to the received information symbols.

15. A communication system with reduced power variation as claimed in any preceding claim wherein each subchannel has an associated transmission format and at least one characteristic of the transmission format of the subchannels is different between at least two subchannels.

16. A communication system with reduced power variation as claimed in claim 15 wherein the at least one characteristic of the transmission format is chosen from the group of:

a) the transmitted power,

b) the order of the information symbols,

c) the order of the channel symbols, and

d) the encoding.

17. A communication system with reduced power variation as claimed in any preceding claim wherein the encoding is dynamically altered.

18. A communication system with reduced power variation as claimed in claim 17 wherein the encoding is dynamically altered in response to the transmit power.

19. A communication system with reduced power variation as claimed in claim 17 or 18 wherein the transmission rate of the information symbols is altered.

20. A communication system with reduced power variation as claimed in any preceding claim wherein an Orthogonal Frequency Division Multiplex (OFDM) subchannel communication scheme is employed.

21. A communication system with reduced power variation as claimed in any preceding claim 1 to 19 wherein a multicode Code Division Multiple Access (CDMA) subchannel communication scheme is employed.

22. A communication system with reduced power variation as claimed in any preceding claim characterised by being a cellular communication system.

23. A method of reducing power variation in a communication system wherein data is transmitted over a plurality of subchannels, the method comprising

generating information symbols,

transmitting channel symbols on individual subchannels in a combined signal,

encoding information symbols into higher order channel symbols at substantially the same symbol rate, the encoding both being in response to a forward error correction scheme and including selection between redundant symbol values to reduce power variation of the combined signal, and

receiving the higher order channel symbols and regenerating the information symbols.

24. A method of reducing power variation in a communication system as claimed in claim 23 wherein the encoding of information symbols into higher order channel symbols is done independently for each subchannel.

25. A method of reducing power variation in a communication system as claimed in any preceding claim 23 to 24 wherein the forward error correcting scheme is a trellis coding scheme.

26. A method of reducing power variation in a communication system as claimed in any of the preceding claims 23 to 25 wherein QPSK information symbols are encoded into 16 QAM channel symbols.

27. A method of reducing power variation in a communication system as claimed in any of the preceding claims 23 to 26 further comprising the step of generating compensation data for reducing the amplitude variations of the combined signal, and wherein the encoding of the channel symbols is in response to the combination of the information symbols and compensation data.

28. A method of reducing power variation in a communication system as claimed in any preceding claim 23 to 27 wherein an Orthogonal Frequency Division Multiplex (OFDM) subchannel communication scheme is employed.

29. A method of reducing power variation in a communication system as claimed in any preceding claim 23 to 27 wherein an multicode Code Division Multiple Access (CDMA) subchannel communication scheme is employed.

30. A method of reducing power variation in a communication system as claimed in any preceding claim 23 to 29 wherein the communication system is a cellular communication system.

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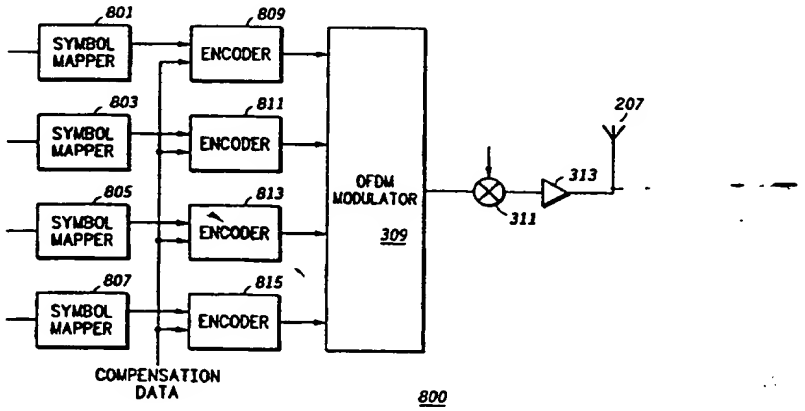
(54) Title: COMMUNICATION SYSTEM WITH REDUCED POWER VARIATION AND METHOD THEREFOR




(57) Abstract

The invention relates to a communication system employing subchannel communication such as OFDM or multicode CDMA. A significant disadvantage of subchannel communication is the power variation of the transmitted signal. The invention provides a system and method with reduced power variation without compromising performance or increasing transmission bandwidth. According to the invention the information symbols to be transmitted on the individual subchannel are fed to encoders (809–815) which maps the information symbols into channel symbols by increasing the order of the symbols. The encoding is both in response to a forward error correction scheme and includes selection between redundant symbol values to reduce power variation of the combined signal. The channel symbols are fed to a modulator (309) and the modulated signal is transmitted. Preferably the encoder comprises a trellis coder jointly encoding the information symbols and compensation data set to reduce the power level variation.

# COMMUNICATION SYSTEM WITH REDUCED POWER VARIATION AND METHOD THEREFOR

## Field of the Invention

The present invention relates to a communication system with reduced power variation wherein data from a transmitter is transmitted to a receiver over a plurality of subchannels and a method therefor. The invention is applicable but not limited to a cellular communication system.

## Background of the Invention

In a cellular communication system each of the mobile stations communicate with typically a fixed base station. Communication from the mobile station to the base station is known as uplink and communication from the base station to the mobile station is known as downlink. The total coverage area of the system is divided into a number of separate cells each covered by a single base station. The cells are typically geographically distinct with an overlapping coverage area with neighbouring cells. As a mobile station moves from the coverage area of one cell to the coverage area of another cell, the communication link will change from being between the mobile station and the base station of the first cell to being between the mobile station and the base station of the second cell. This is known as a handover. Specifically, some cells may lie completely within the coverage of other larger cells.

All base stations are interconnected by a fixed network. This fixed network comprises communication lines, switches, interfaces to other communication networks and various controllers required for operating the network. A call from a mobile station is routed through the fixed network to the destination specific for this call. If the call is between two mobile stations of the same communication system the call will be routed through the fixed network to the base station of the cell in which the other mobile station currently is. A connection is thus established between the two serving cells through the fixed network. Alternatively, if the call is between a mobile station and a telephone connected to the

symbols at substantially the same symbol rate, the encoding both being in response to a forward error correction scheme and including selection between redundant symbol values to reduce power variation of the combined signal, and a subchannel receiver receiving the higher order channel symbols and regenerating the information symbols.

Preferably, the average symbol energy of the channel symbols is substantially the same as the information symbols and the encoding of information symbols into higher order channel symbols is done independently for each subchannel.

According to a preferred feature of the invention the forward error correcting scheme is a trellis coding scheme.

According to a second preferred feature of the invention, the encoder comprises a first data input for the information symbols and at least a second data input for compensation data, the communication system further comprising means for generating compensation data reducing the amplitude variations of the combined signal.

Preferably, the communication scheme employed is an Orthogonal Frequency Division Multiplex (OFDM) subchannel communication scheme or a multicode Code Division Multiple Access (CDMA) subchannel communication scheme.

According to a second aspect of the invention, there is provided a method of reducing power variation in a communication system wherein data is transmitted over a plurality of subchannels, the method comprising generating information symbols, transmitting channel symbols on individual subchannels in a combined signal, encoding information symbols into higher order channel symbols at substantially the same symbol rate, the encoding both being in response to a forward error correction scheme and including selection between redundant symbol values to reduce power variation of the combined signal, and receiving the higher order channel symbols and regenerating the information symbols.

FIG. 8 is a block diagram of a 4 channel OFDM subchannel transmitter in accordance to the invention.

FIG. 9 is an illustration of the constellation points for a BPSK symbol and an 8-PSK symbol.

FIG. 10 is an illustration of an example of a trellis coder.

## Description of a Preferred Embodiment

FIG. 1 illustrates a cellular communication system 100. In the system, a base station 101 communicates with a number of mobile station 103 over radio channels 105. In the cellular system, the base station 101 covers users within a certain geographical area 107 whereas other geographical areas 109, 111 are covered by other base stations 113, 115. Typically, each of the base stations 101, 113, 115 contain a broadcast carrier plus one or more traffic carriers.

FIG. 2 illustrates an example of a link between one mobile station 103 and one base station 101 using a subchannel modulation scheme. In the example, the data from a single data source 201 is separated into subchannels in a serial to parallel converter 203. Alternatively, the data on different subchannels may originate from different data sources. The serial to parallel converter 203 is connected to a subchannel transmitter 205 which modulates the data , amplifies and transmits the modulated signal over the radio channel 209 by use of an antenna 207. The signal is received by a receive antenna 211 connected to a subchannel receiver 213 which regenerates the data transmitted on each individual subchannel. In the example, the data received in the subchannels are combined into a single data stream by a parallel to serial converter 215.

FIG. 3 illustrates the principle of a 4 subchannel transmitter 300 using an OFDM modulation scheme. The data in each subchannel is fed to a symbol mapper 301-307 which maps the data into a complex symbol for transmission on the subchannel. The

integrators are fed to data detectors 421 - 427 which estimates the received symbol and maps it into the received data in the subchannel.

A more detailed description of OFDM modulation can be found in 'COFDM modulation: an overview' by W.Y.Zou and Y.Wu in IEEE Transactions on Broadcasting Vol. 41 No.1 pp 1-8, March 1995.

FIG. 5 illustrates an example of a 2 channel subchannel transmitter 500 using a multicode CDMA subchannel modulation scheme. The input data in the two subchannels are mapped into complex symbols by the symbol mappers 501, 503. The complex symbols are multiplied by a first spreading code in multipliers 505, 507. The first spreading code is different for each subchannel and preferably the spreading codes are orthogonal between the channels. The two channels are added together in an adder 509 and the sum is in this example spread by multiplication in a second multiplier 511 by a common spreading code. The output of the multiplier is fed to a quadrature modulator 513 and the resultant signal is amplified in an amplifier 515 before being transmitted by the antenna 517.

FIG. 6 illustrates the principle of a multicode CDMA 2 channel subchannel receiver 600. The radio signal is received by an antenna 601 and amplified in a low noise amplifier 603. The output of the amplifier 603 is fed to a quadrature down converter which generates complex base band signal. This signal is de-spread by the common spreading code in a multiplier 607 before being fed to multipliers 609, 611 where the signal is de-spread with the spreading code in each subchannel. The output of the multipliers 609, 611 is fed to symbol time integrators 613,614. The signal for the other subchannel will for orthogonal spreading codes integrate to zero whereas the wanted signal following de-spreading will be restored to the non spread signal transmitted in this subchannel. the output of the integrators is fed to data detectors 617,619 which estimates the received symbol and generates the received data in the subchannel.

Further description of CDMA communication systems can be found in ' Spread Spectrum CDMA Systems for Wireless Communications' by Savo Glisic and Branca Vucetic, Artech House, 1997, ISBN 0-89006-858-5 and in 'Multi-Carrier Spread Spectrum

channel symbols and selecting between redundant symbol values so that the power variation is reduced. In addition, the order of the symbols are increased to allow forward error correcting coding to compensate for reduction in the minimum distance between the symbols.

The term 'information symbols' denotes the data symbols directly corresponding to the source data in the appropriate subchannel before any processing such as forward error correcting coding. 'Channel symbols' denote the symbols actually transmitted over the radio link and thus include any forward error correcting coding etc. A channel symbol being of higher order than an information symbol means that there are more constellation points of the symbol, such as for example a QPSK symbol being of higher order than a BPSK symbol.

The embodiment is described in more detail in the following for the specific example where the data to be transmitted on each subchannel is mapped into Binary Phase Shift Keying (BPSK) symbols. FIG. 8 illustrates the embodiment for a 4 channel OFDM subchannel transmitter 800 corresponding to the one illustrated in FIG. 3. The symbol mappers 301-307 are in this case specifically BPSK symbol mappers 801-807. The output of the symbol mappers 801-807 are fed to encoders 809-815 which encode the information symbols into channel symbols by increasing the order of the symbols and using the increased redundancy to reduce power variation and include forward error correcting coding.

Preferably, the encoder will map the BPSK signal into 8 point Phase Shift Keying (8 PSK) using 2 bit trellis coding. FIG. 9 illustrates the constellation points for a BPSK symbol (FIG. 9(a)) and an 8-PSK symbol (FIG. 9(b)). FIG. 10 illustrates an example of a trellis coder 1000 which comprises two data inputs 1001,1003, the second input being fed to a binary multiplier 1005 which together with two delay elements 1007, 1009 generates a third binary value and introduces convolutional encoding. The three binary data values are fed to a data mapper 1011 which maps the data vector into the corresponding constellation point. A more detailed description of trellis coding can be found in 'Trellis-coded Modulation with Redundant Signal Sets Part 1: Introduction' by G. Ungerboeck in

operation and the optimum choice of compensation data is stored in a memory unit. During operation the set of data to be transmitted during the burst is fed to the memory unit, and the corresponding set of compensation data is obtained on the output of the memory unit.

When receiving the transmitted signal, the receiver demodulates and decodes the trellis code as is known in the art. However, as the first data input 1001 does not carry any information but is solely used for reducing the power variation of the transmission, the corresponding bit can be ignored in the receiver.

As one channel symbol is generated for each information symbol, the symbol rate and thus bandwidth of the transmission does not increase by the trellis coding and power variation reduction. Furthermore, the energy per symbol of the information and channel symbols is preferably maintained identical. As the minimum distance between constellation points is reduced, the uncoded symbol error is increased but this is compensated for by the trellis coding. The invention thus provides reduction of the peak to average power ratio without increasing the transmit power or bandwidth of the transmission.

According to an alternative embodiment the forward error correcting coding is not done independently on each subchannel but is done by applying error correction to the set of data across the subchannels. In this embodiment the channel symbol in one subchannel will depend on the information symbols in other subchannels and not just on the information symbols in the current subchannel.

In a different embodiment of the invention applicable to a subchannel CDMA transmitter with QPSK information symbols, the information symbols are encoded into 16 QAM (Quadrature Amplitude Modulation) using Trellis Coding. This results in similar performance as QPSK for the same transmission bandwidth and power, and provides a redundant bit for rotating each channel symbol permitting reduction in power level variations. This embodiment is suitable for the Universal Mobile Telecommunication

transmissions only occur on some subchannels whereas other subchannels have no transmissions. Preferably, the encoding is performed independently on each subchannel in this embodiment.

Alternatively or in addition the power level of the transmissions in each subchannel may be different and the corresponding encoding can vary accordingly. For example if four subchannels are transmitted at say twice the power level of four other subchannels, the encoding for reduced power variation according to the current invention may be applied to these four subchannels only.

The encoding and application of the described technique can be dynamically altered to suit the current needs and conditions. Specifically, in a cellular communication system the transmitted power of a mobile station will vary with the distance between the base station and the mobile station. When the mobile station is far from the base station the transmitted power will be close to the maximum and in order to ensure a high efficiency without distortion of the transmitted signal the power variations must be reduced to a minimum. However, when the mobile station is close to the base station a substantially lower power level is transmitted and the efficiency will not be significantly affected by power variations. At the low power level the power amplifier will furthermore not be close to clipping or non-linear amplification and the distortion is thus reduced significantly.

Accordingly, the technique for reducing power variations may only be applied to mobile stations close to the edges of the cells but not to mobile stations close to the base station and hence transmitting at low power. A more flexible approach is to alter the information and channel symbol transmission rates and thus the encoding algorithm according to the current conditions.

The symbol mappers, encoders and the memory unit are preferably implemented in a suitable processor, such as a microprocessor or digital signal processor with associated memory, or is alternatively implemented in an integrated circuit.

## Claims

1. A communication system with reduced power variation wherein data is transmitted over a plurality of subchannels including

at least one means of generating information symbols,

at least one encoder for encoding information symbols into higher order channel symbols at substantially the same symbol rate, the encoding both being in response to a forward error correction scheme and including selection between redundant symbol values to reduce power variation of the combined signal, and

a subchannel transmitter for transmission of channel symbols on individual subchannels in a combined signal.

2. A communication system with reduced power variation wherein data is transmitted over a plurality of subchannels further including

a subchannel receiver receiving the higher order channel symbols and regenerating the information symbols.

3. A communication system with reduced power variation as claimed in claim 1 or 2 wherein the encoding of information symbols into higher order channel symbols is done independently for each subchannel.

4. A communication system with reduced power variation as claimed in claim 1 or 2 wherein the forward error correcting scheme operates on a plurality of the subchannels.

5. A communication system with reduced power variation as claimed in any preceding claim wherein the forward error correcting scheme is a trellis coding scheme.

6. A communication system with reduced power variation as claimed in any of the preceding claims 1 to 5 wherein BPSK information symbols are encoded into 8PSK channel symbols.

compensation data with a local replica of the compensation data corresponding to the received information symbols.

15. A communication system with reduced power variation as claimed in any preceding claim wherein each subchannel has an associated transmission format and at least one characteristic of the transmission format of the subchannels is different between at least two subchannels.

16. A communication system with reduced power variation as claimed in claim 15 wherein the at least one characteristic of the transmission format is chosen from the group of :

a) the transmitted power,

b) the order of the information symbols,

c) the order of the channel symbols, and

d) the encoding.

17. A communication system with reduced power variation as claimed in any preceding claim wherein the encoding is dynamically altered.

18. A communication system with reduced power variation as claimed in claim 17 wherein the encoding is dynamically altered in response to the transmit power.

19. A communication system with reduced power variation as claimed in claim 17 or 18 wherein the transmission rate of the information symbols is altered.

20. A communication system with reduced power variation as claimed in any preceding claim wherein an Orthogonal Frequency Division Multiplex (OFDM) subchannel communication scheme is employed.

21. A communication system with reduced power variation as claimed in any preceding claim 1 to 19 wherein a multicode Code Division Multiple Access (CDMA) subchannel communication scheme is employed.

28. A method of reducing power variation in a communication system as claimed in any preceding claim 23 to 27 wherein an Orthogonal Frequency Division Multiplex (OFDM) subchannel communication scheme is employed.

29. A method of reducing power variation in a communication system as claimed in any preceding claim 23 to 27 wherein an multicode Code Division Multiple Access (CDMA) subchannel communication scheme is employed.

30. A method of reducing power variation in a communication system as claimed in any preceding claim 23 to 29 wherein the communication system is a cellular communication system.

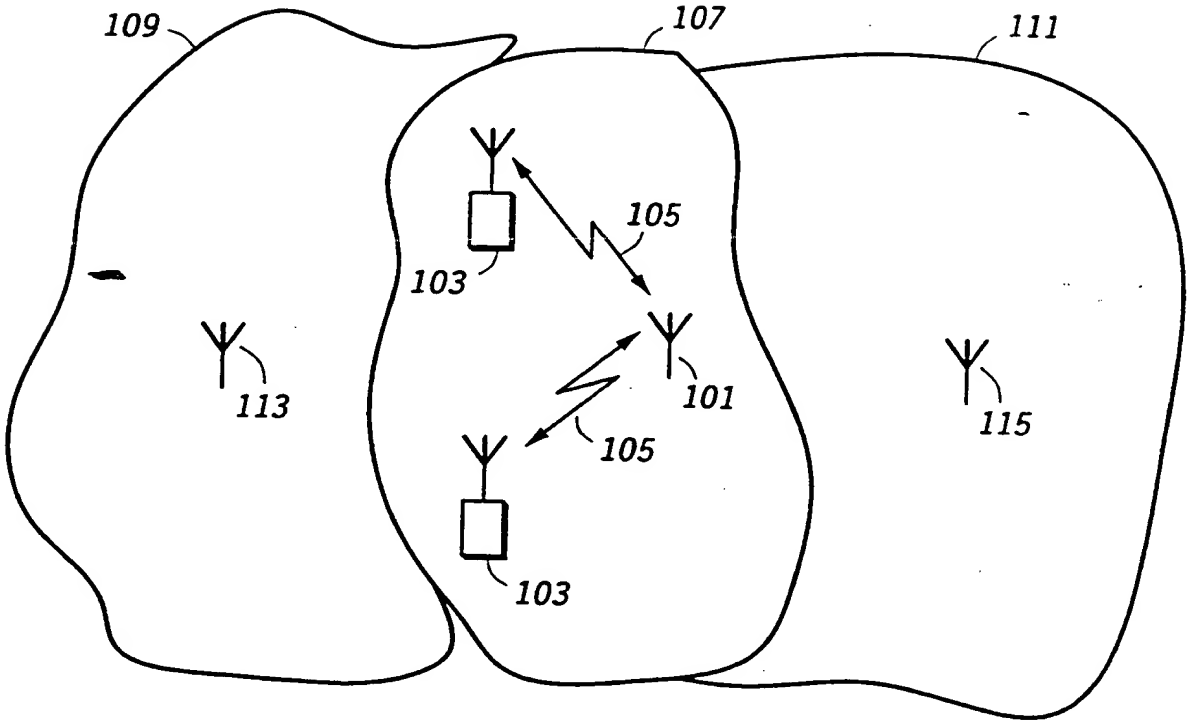



FIG.1
-PRIOR ART-

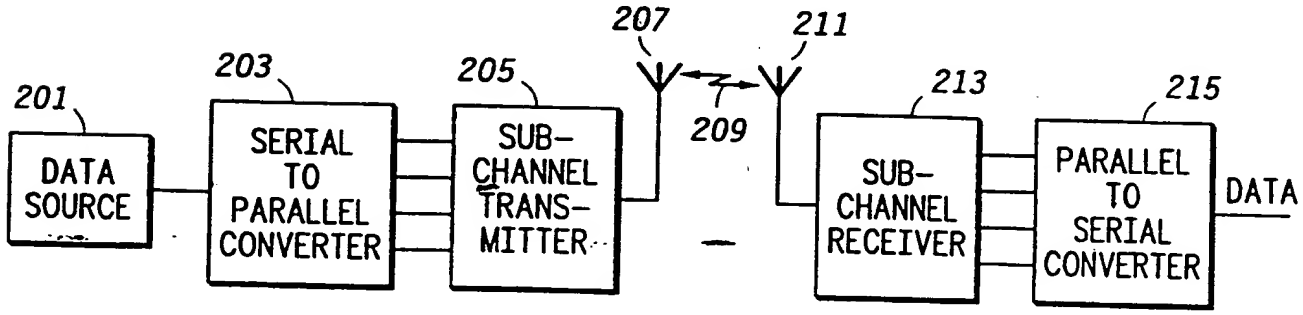
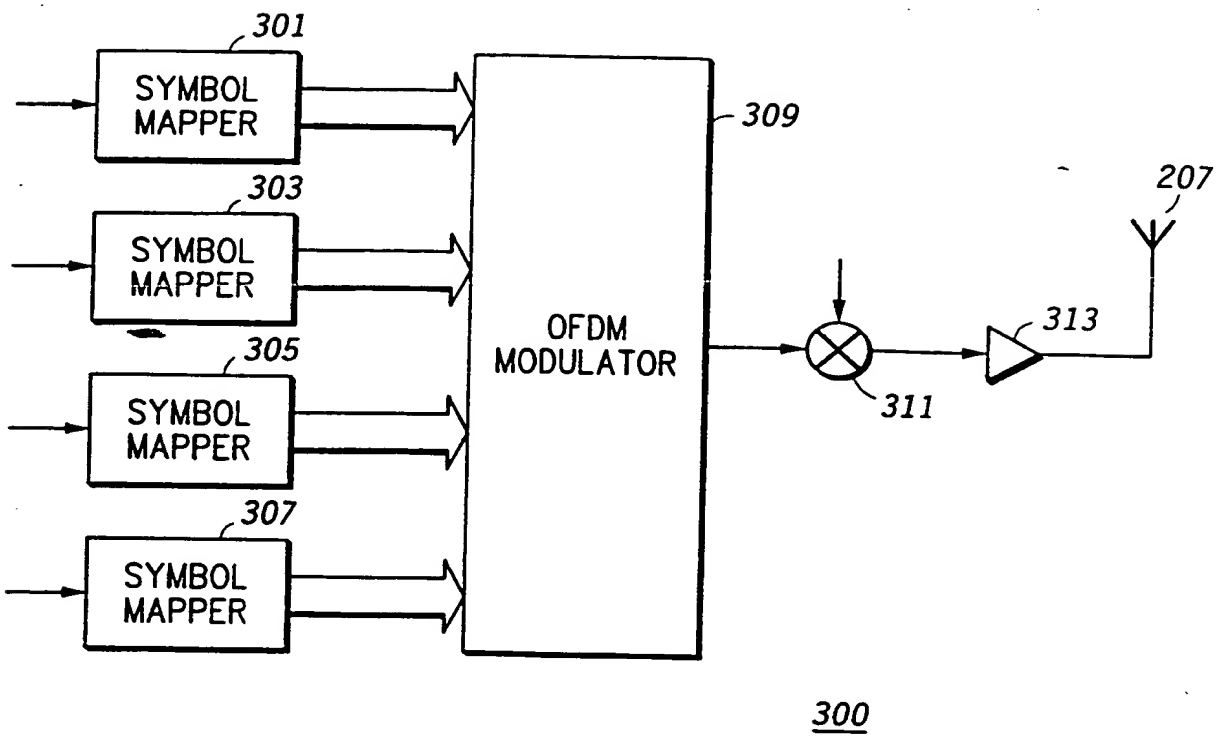



FIG.2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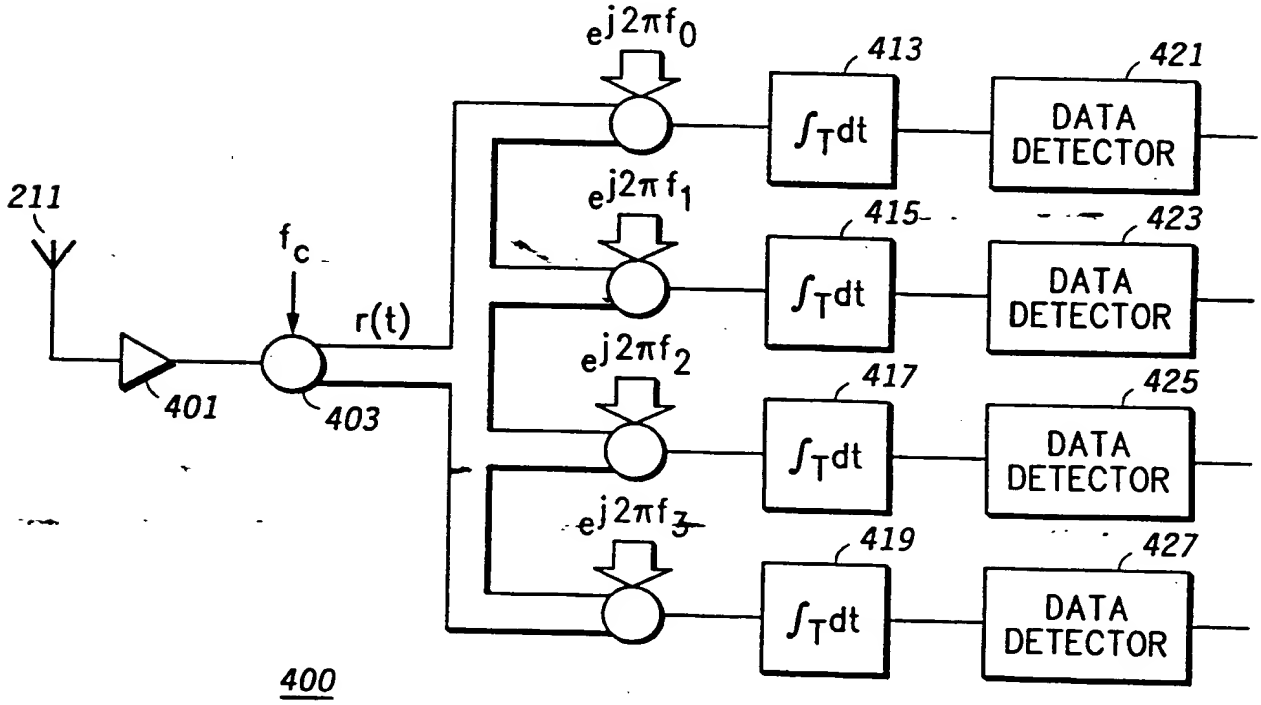
SYMBOL MAPPER
303
SYMBOL MAPPER
305
SYMBOL MAPPER
307
SYMBOL MAPPER
309
OFDM MODULATOR
311
313
207
300

FIG.3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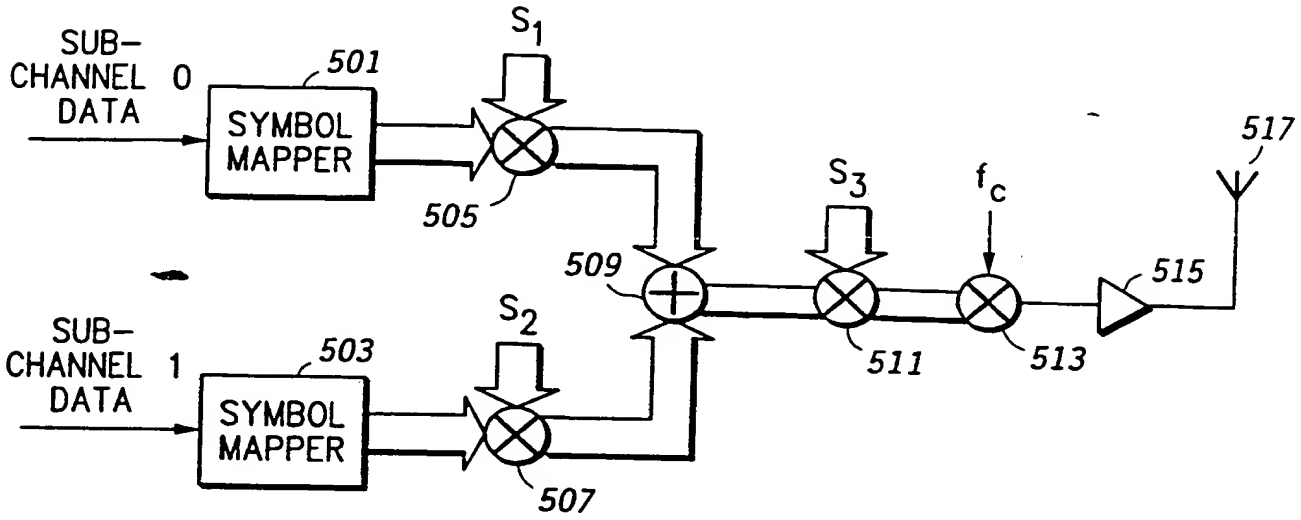
413
415
417
419
DATA DETECTOR
421
423
425
427
400

FIG.4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505
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CHANNEL 1
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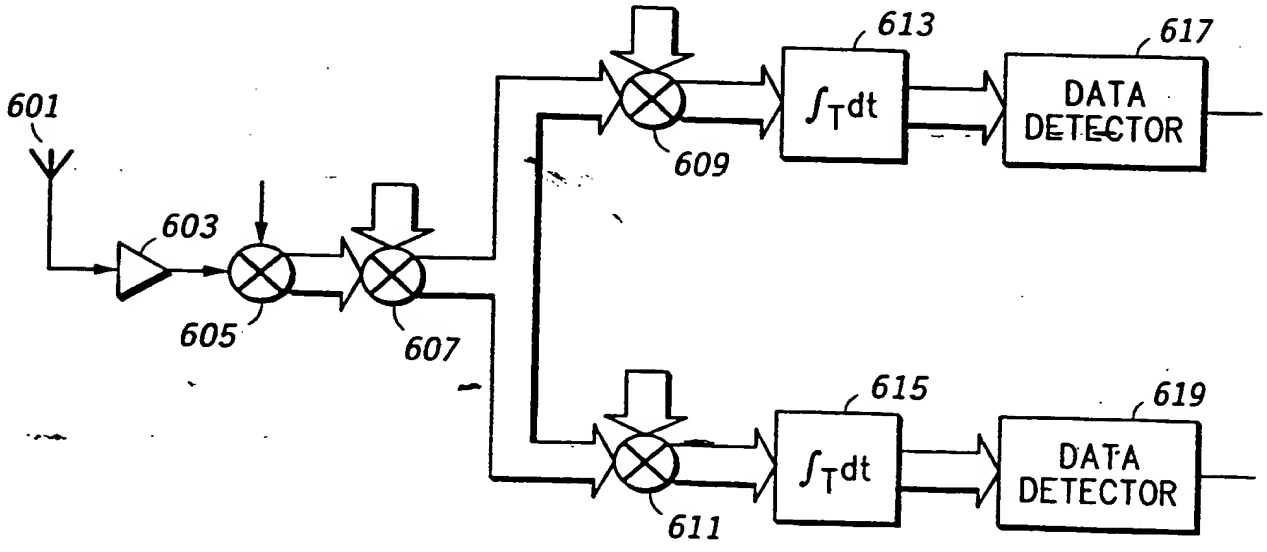
FIG. 5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DETECTOR
600

FIG. 6

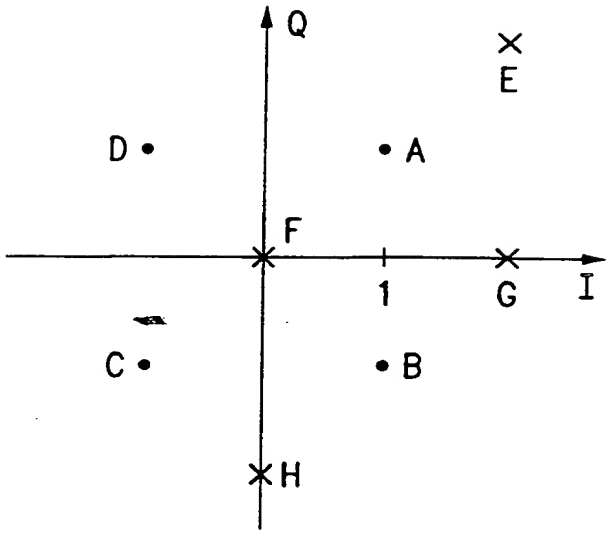



FIG. 7A

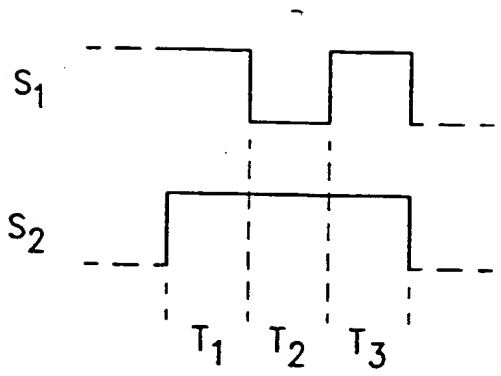



FIG. 7B

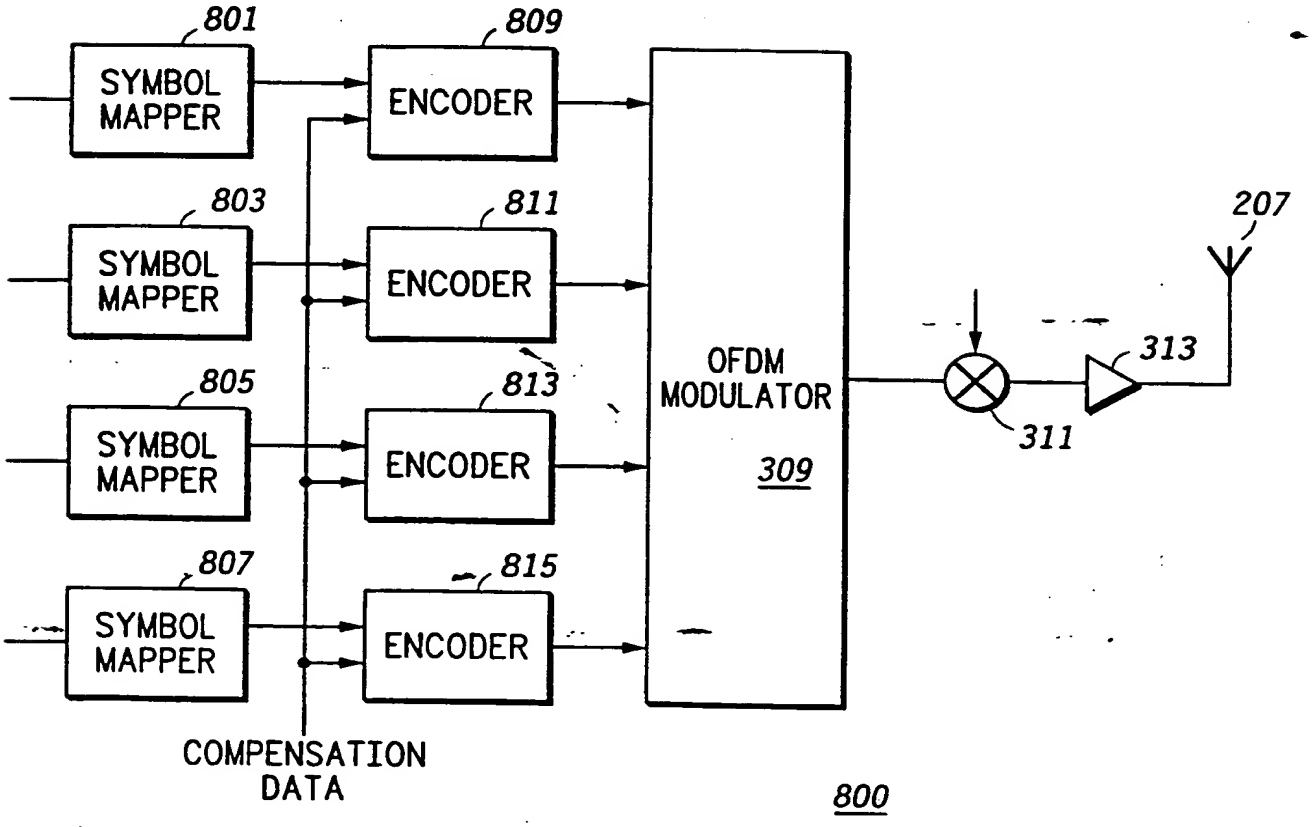



FIG. 8

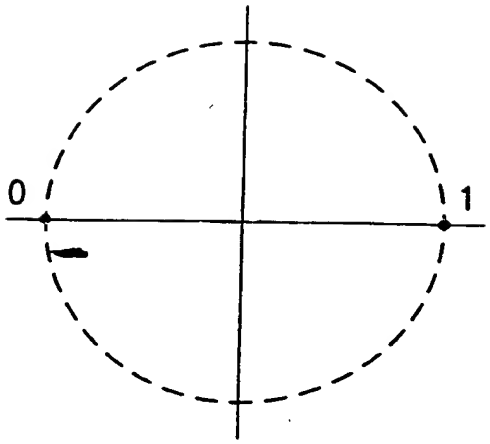



FIG.9A

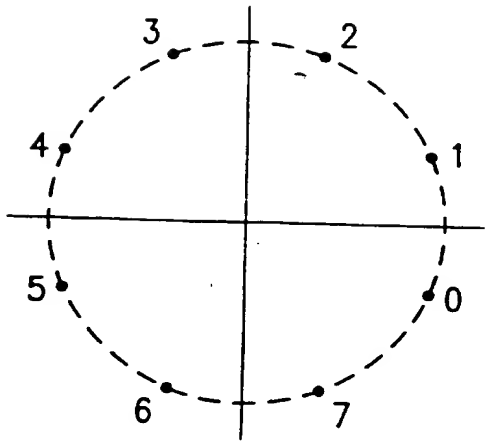
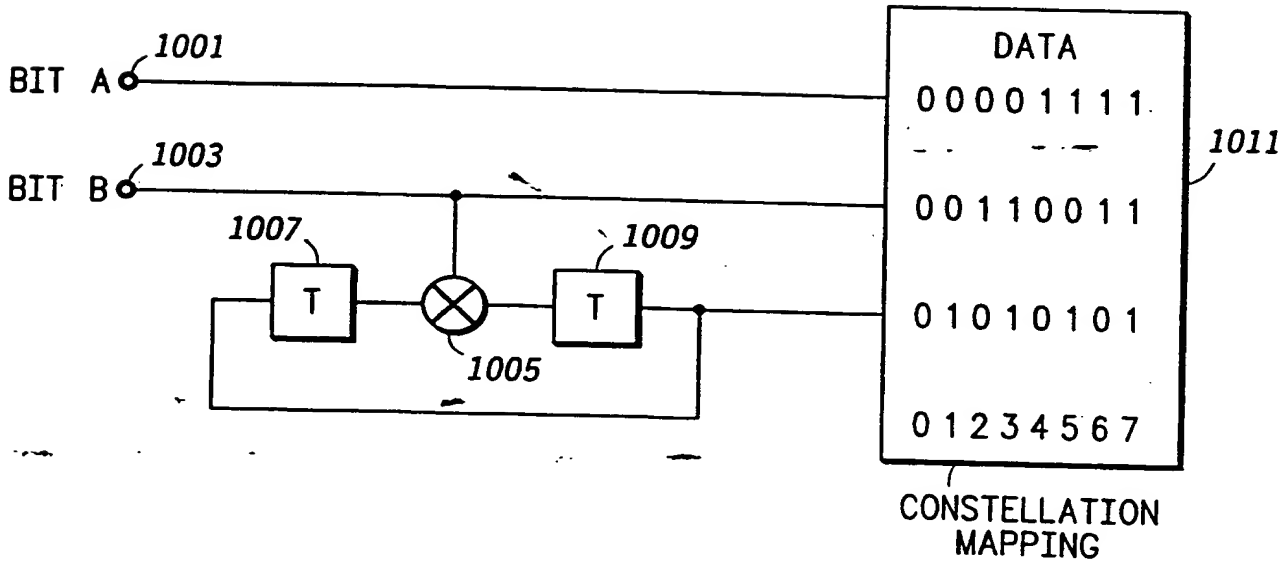



FIG.9B




1000

FIG.10

# INTERNATIONAL SEARCH REPORT

Inte[redacted] Application No
PCT/EP 99/04734

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 H04L27/26 H04L27/34 H04L27/18 H04L1/24 H04L1/12

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
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| A | | 8-14, 17-19 |

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | Koukourlis, S |

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